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INSTITUTE OF THE AERONAUTICAL SCIENCES

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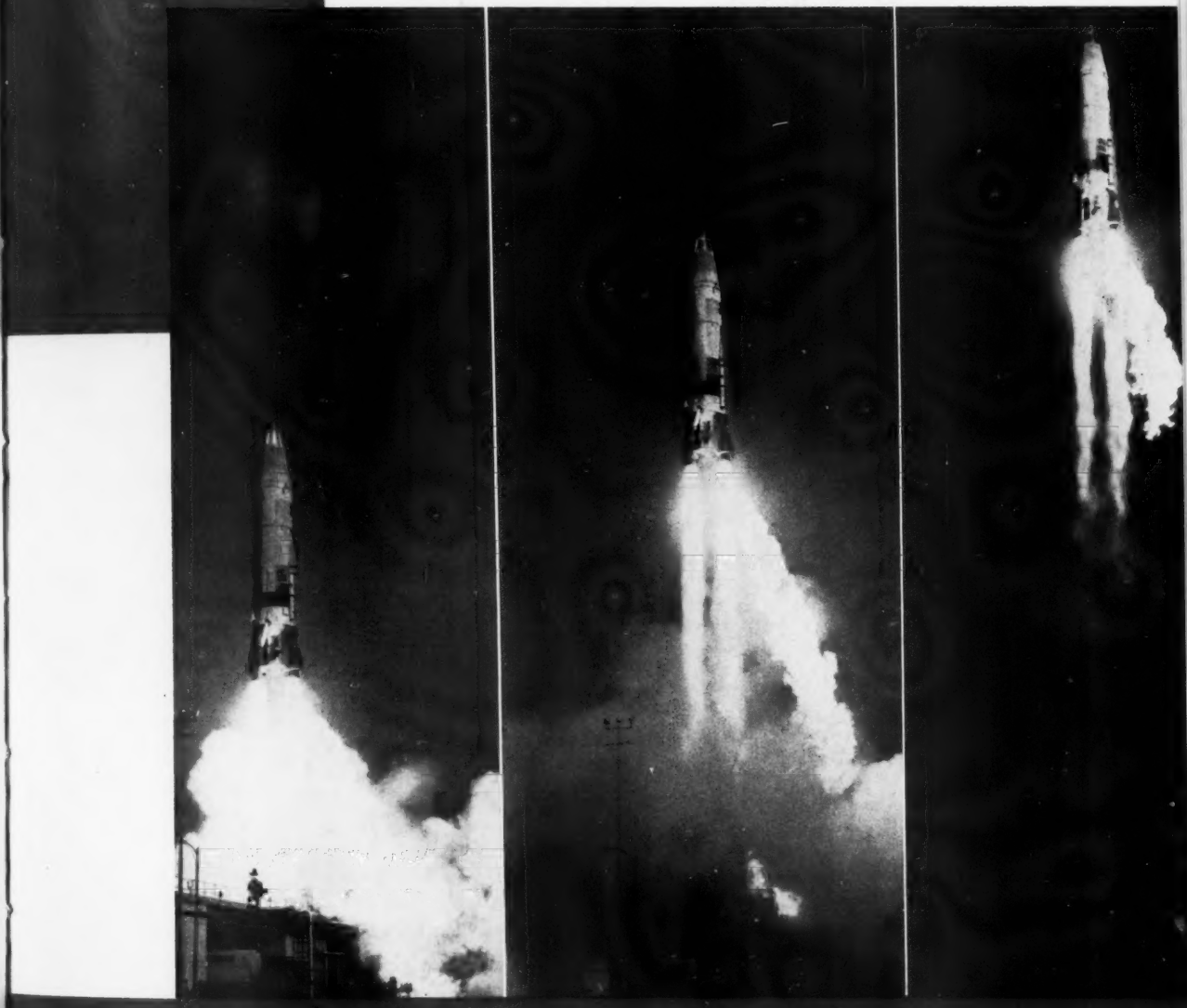

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The Structure of Our Space

April, 1958

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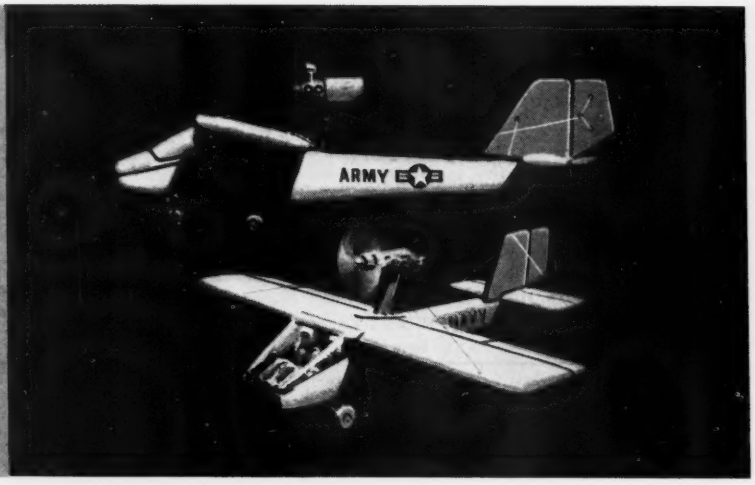

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Vol. 17—No. 4 April, 1958

Aeronautical Engineering REVIEW

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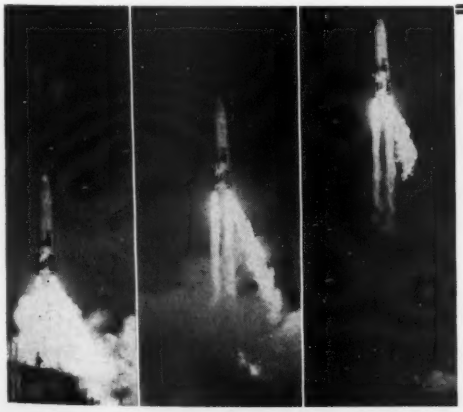

Cover—A recent launching of the Atlas ICBM is shown in these first sequence photos released by the Air Force. In the sequence on the left two incandescent jets from the rocket engines become visible as the Atlas climbs clear of its wake. The expendable launcher tubing on pad burns in the center photo. The plume of flame spurting diagonally from the missile base is exhaust from the fuel system turbopumps. The photo on the right shows the Atlas on its way to a successful flight. Convair Division of General Dynamics Corporation is testing the Atlas at Cape Canaveral, Fla.

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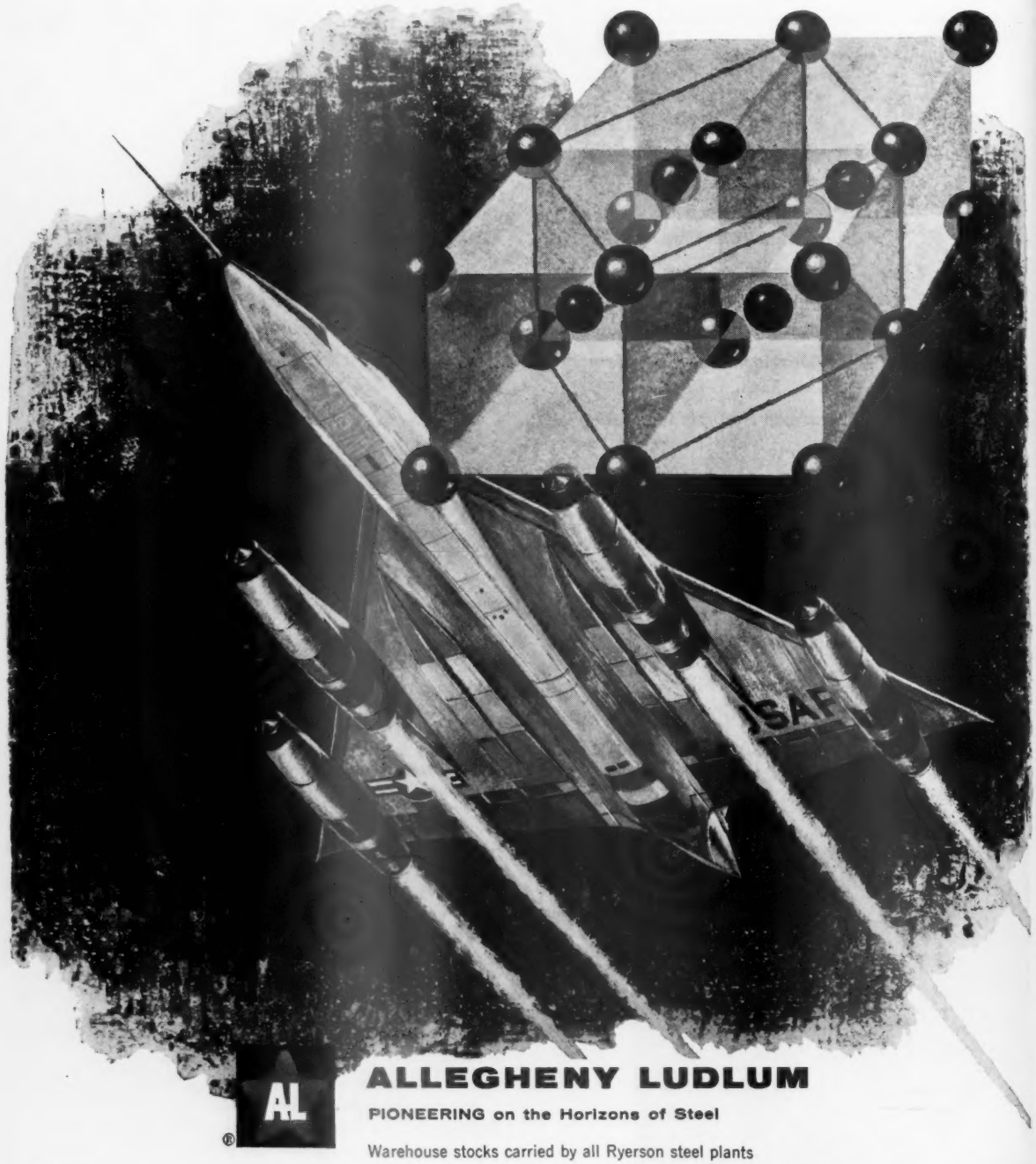

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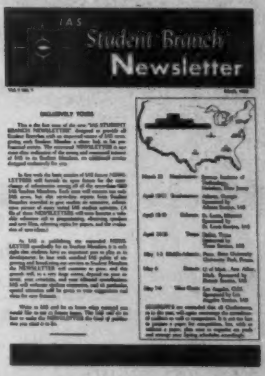
IAS News Notes

April 1958

THE IAS has begun publication of a NEWSLETTER for its more than 4,000 Student Members. Designed to provide 73 Student Branches with their own source of IAS news, the NEWSLETTER will give each student a close link to activities in his chosen career. Providing an open forum for the interchange of information, the NEWSLETTER is another indication of strong and continued interest by the IAS in Aeronautical Engineers of the future. First issue cover is illustrated here.



NATIONAL MEETINGS CALENDAR

Apr. 28-30	Second Annual Air Force Office of Scientific Research Astronautics Symposium, Shirley-Savoy Hotel, Denver, Col. Sponsored by IAS.
May 12-14	National Midwestern Meeting on Guided Missiles (CLASSIFIED), Hotel Chase, St. Louis, Mo.
May 12-14	National Conference on Aeronautical Electronics, Dayton, Ohio. IRE-IAS participating.
June 2-4	National Telemetering Conference, Lord Baltimore Hotel, Baltimore, Md. Sponsored by IAS, ARS, ISA, and AIEE.
June 19-20	1958 Heat Transfer and Fluid Mechanics Institute, University of California, Berkeley, Cosponsored by IAS.
July 8-11	National Summer Meeting, Ambassador Hotel, Los Angeles, Calif.
Sept. 8-13	First International Congress, International Council of the Aeronautical Sciences, Palace Hotel, Madrid, Spain.
Oct. 7-8	Canadian Aeronautical Institute-IAS 1958 Joint Meeting, Chateau Laurier, Ottawa, Canada.
Dec. 17 1959	Wright Brothers Lecture, Washington, D. C.
Jan. 26-29	Twenty-Seventh Annual Meeting, Sheraton-Astor Hotel, New York. Honors Night Dinner, Tuesday, January 27.

REGIONAL STUDENT CONFERENCES

Apr. 10-11	Southeastern: Atlanta, Georgia. Sponsored by Atlanta Section.
Apr. 18-19	St. Louis: St. Louis, Mo. Sponsored by St. Louis Section.
Apr. 24-26	Texas: Dallas, Texas. Sponsored by Texas Section.
May 1-3	Middle-Atlantic: Pennsylvania State University, University Park, Pennsylvania.
May 6	Detroit: University of Michigan, Ann Arbor, Michigan. Sponsored by Detroit Section.
May 7-9	West Coast: Los Angeles, California. Sponsored by Los Angeles Section.

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XUM

ELECTRONICS-NAVIGATION-GUIDANCE-CONTROL! These important fields will get full coverage in the Technical Articles Section of next month's REVIEW. Each contribution, prepared by invitation, will appear exclusively.

SECTION MEETINGS CALENDAR

Apr. 8 Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Compressible Turbulent Boundary Layer with Heat Transfer" by Eli Reshotko.

Apr. 8 San Antonio Section: Dinner Meeting, Ft. Sam Houston Officers Club, (social at 6:30, dinner at 7:30). "Forms of Energy Available to Man" by John J. Grebe.

Apr. 8 Washington Section: Dinner Meeting, Occidental Restaurant, (social at 6, dinner at 6:45). "Missile and Spacecraft Electronics" by George S. Valley.

Apr. 8 Tulsa Section: Dinner Meeting, Alvin Plaza Hotel, (social at 6:15, dinner at 7). "Why Jet Transports?" by Marvin Whitlock.

Apr. 10 Baltimore Section: Dinner Meeting, Aberdeen Officers Club, (social at 6, dinner at 7). "The Army and Ballistic Missiles" by Major General John B. Medaris.

Apr. 14 Indianapolis Section: Dinner Meeting, Purdue Memorial Union, 7 p.m. "The Real Time Simulation of Turbojet and Turboprop Engines and Controls" by D. L. Dresser.

Apr. 15 San Diego Section: Technical Meeting, IAS Building, 8 p.m. "Application of Pre-Stressed Ceramics to High Speed Flight" by W. Knapp.

Apr. 17 Los Angeles Section: Dinner Meeting, IAS Building, time to be announced. "Los Angeles International Airport Prepares for the Jet Age" by Don Belding and Donald Wilcox.

Apr. 17 San Francisco Section: Dinner Meeting, Ramor Oaks Restaurant, (social at 6:30, dinner at 7). "The Atmosphere in Missile Design and Operation" by George F. Taylor.

Apr. 17 Rocky Mountain Section: Dinner Meeting, Lowry AFB Officers Club, (social at 6:30, buffet at 7). "Engineering Curriculum of the Air Force Academy" by Lt. Col. G. C. Clementson, and "Facilities at the Air Force Academy" by Capt. J. R. Plitt.

Apr. 22 Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Experiments on Chemical Kinetics in Supersonic Flow" by P. Wegener.

Apr. 23 Chicago Section: Dinner Meeting, 6 p.m. Films, demonstration and visit to Argonne National Laboratory. (Limited to 100 persons). Several speakers - Atomic Power and Nuclear Research.

Apr. 24 Kansas City Section: Joint IAS-SAE Dinner Meeting, Am. Legion Memorial Building, (social at 6:30, dinner at 7). "A Review of the Entire USAF Guided Missile Program" by Maj. Gen. M. C. Demler.

Apr. 24 Dayton Section: General Meeting, place to be announced. "Future Propulsion Systems for Spacecraft" by Addison M. Rothrock.

Apr. 29 San Diego Section: Technical Meeting, IAS Building, 8 p.m. "Air Traffic Control" by J. Frank Yore.

IAS News

A Record of People and Events of Interest to Institute Members

Second Annual Astronautics Symposium

THE INSTITUTE OF THE AERONAUTICAL SCIENCES and the Air Force Office of Scientific Research, ARDC, will combine talents for the Second Annual AFOSR Astronautics Symposium in Denver, April 28–30, at the Shirley-Savoy Hotel.

The Symposium will be highlighted by four technical sessions, a panel discussion, and a field trip. Conference Co-Chairmen and organizers are Morton Alperin, Director of Advanced Studies, AFOSR, and Colonel Paul Dane, Thermodynamics Professor, USAF Academy, and Chairman, IAS Rocky Mountain Section.

The panel discussion, "Assume a Capability for Manned Space Operation—For What Purposes Should This Capability Be Utilized?" will be undertaken by seven prominent scientists: William H. Pickering, California Institute of Technology, Jet Propulsion Laboratory; Fred Whipple, Smithsonian Institute Astrophysical Observatory; Jack Froehlich, California Institute of Technology; Paul Rosenberg, Rosenberg Associates; R. Bucheim, The RAND Corporation; A. Spilhaus, University of Minnesota; and G. Gamow, University of Colorado.

Principal speaker at a banquet on April 28 (Monday, 7:30 p.m.) will be Clifford C. Furnas, an IAS Fellow and Chancellor, University of Buffalo.

Dr. Pickering, as a luncheon speaker on April 29 (Tuesday, at noon), will discuss the Jupiter Satellite Program. "The Far Side Research Concept" will be discussed by luncheon speakers Morton Alperin and Major E. Davis, AFOSR, on April 28 (Monday, at noon).

General Gregory's Comments

Host for the Air Force, Brig. Gen. H. F. Gregory, Commander, Air Force Office of Scientific Research, ARDC, has set the tone of the conference with the following remarks:

"AFOSR sponsored the first astronautics symposium because of Air Force concern with the urgent need to gather together the knowledge existing in the several scientific disciplines for an intensive examination of the state of the art in an area of increasing military importance. The 1958 astronautical symposium takes place at a time when the exploration of the space beyond our atmosphere has actually, physically begun. Last year astronautics was still only a gleam in our eye. This year that gleam is a lusty infant. I am confident that most of those who will attend the 1958 sessions will live to see the astronautical sciences well on their way to healthy maturity."

Technical Papers

Technical papers scheduled for presentation include the following:

Monday, April 28, 9:30 a.m. to 12 noon: *Space Environment and Vacuum Research Session*—Lt. Col. C. W. Craven, Chairman. "Vacuum Chamber Research" by R. Roche, Litton Industries; "Experiments From a Lunar Vehicle" by Dr. M. Johnson, Aeronutronic Systems, Inc.; "Cosmic Debris of Interplanetary Space" by Dr. M. Dubin, AFCRC, ARDC; "Research on Space Components" by Capt. D. Fulgham, WADC, ARDC.

Monday, 2 p.m. to 4:30 p.m.: *Control and Propulsion of Vehicles Outside the Atmosphere Session*—Dr. A. Hall, The Martin Company, Chairman. "Preliminary Considerations on Instrumentation of an Earth-Man-Earth Flight" by Dr. E. Frey, Massachusetts Institute of Technology; "Plasma Jet Propulsion" by D. Howard, Giannini Research Laboratories; "Some Considerations Pertaining to Space Navigation" by Y. C. Lee, Aerojet-General Corporation; "A Description of a Propulsive Device which Employs a Magnetic Field as the Driving Force" by Dr. R. Patrick, Avco Research Laboratory; "Problems of Thrust Production by Electro-Static Fields" by Dr. D. Langmuir, The Ramo-Wooldridge Corp.

Tuesday, April 29, 9:30 a.m. to 12 noon: *Panel discussion*, Col. Paul Campbell, AFOSR, Chairman.

Tuesday, 2 p.m. to 4:30 p.m.: *Departure, Space Navigation, and Re-Entry Problems Session*—Simon Ramo, The Ramo-Wooldridge Corporation, Chairman. Paper by Antonio Ferri, Polytechnic Institute of Brooklyn, to be announced; "The Difference Between Satellite and Ballistic Missile Re-Entry Problems" by Fred R. Riddle, Avco Research Laboratory; "Comparative Performance of Ballistic and Low Thrust Vehicles for Interplanetary Flight" by Dr. J. Irving, The Ramo-Wooldridge Corporation; "Free Flight Missile Trajectory" by M. Anthony, The Martin Company; "Flight Mechanics of a Low Thrust Space Vehicle" by Frank Perkins, Convair, A Division of General Dynamics Corporation.

Brig. Gen. H. F. Gregory

Tuesday Evening, 8 p.m. to 10 p.m.: *The Earth's Moon Session*—Morton Alperin, AFOSR, Chairman. "How Much Dust on the Moon" by Dr. T. Gold, Harvard College Observatory; "On the Lunar Dust Layer" by Fred Whipple, Smithsonian Astrophysical Observatory; "Lunar Surface Features, Internal Development of the Moon and Particle Content of Interplanetary Space" by Dr. G. Kuiper, Yerkes Observatory.

The visit to The Martin Company and the Air Force Academy has been scheduled from 8:30 a.m. to 3 p.m. on Wednesday, April 30.

XUM

IAS National Midwestern Meeting to Report Guided Missile Progress

Conclave in St. Louis, May 12–14; Holaday Dinner Speaker

Ben G. Bromberg
Technical Program Chairman

A program of more than 35 technical papers has been scheduled for the IAS National Midwestern Meeting on Guided Missiles in St. Louis, May 12–14.

All papers will be presented in ten sessions classified Secret at McDonnell Aircraft Corporation. Meeting headquarters will be the Hotel Chase.

Principal speaker at a banquet on Monday, May 12, will be William M. Holaday, Director, Guided Missiles, Department of Defense. Luncheon speakers scheduled are Rear Adm. Kleber S. Masterson, Director, Guided Missiles Division, Naval Operations, on Monday, May 12, at McDonnell Engineering Auditorium; and Major Gen. Bernard A. Schriever, Chief, Air Force Ballistic Missile Division, ARDC, at McDonnell on Tuesday, May 13.

Session Chairmen

A list of sessions and probable chairmen includes: *Propulsion I*, Eugene Miller, Director of Research, Olin Mathieson Corporation; *Propulsion II*, Maurice J. Zucrow, Professor, Gas Turbines and Jet Propulsion, Purdue University; *Guidance and Control I*, William F. Ballhaus, Chief Engineer, Northrop Aircraft, Inc.; *Guidance and Control II*, Peter Waterman, Naval Ordnance Laboratory; *Engineering Management in Missile Development*, L. Eugene Root, Vice-President and General Manager, Lockheed Missile Systems Division; *Operational Analysis*, Elmer P. Wheaton, Chief Missile Engineer, Douglas Aircraft; *Aerodynamics and Ballistics*, William Bollay, President and Technical Director, Aerophysics Development Corporation; *Composite Design*, Joseph G. Beerer, General Manager, Missile Development Division, North American Aviation, Inc.; *Astronautics*, Werner von Braun, Redstone Arsenal; *Structures and Aerodynamic Heating*, Kendall Perkins, Vice-President, Engineering, McDonnell Aircraft.

Technical Papers

Although the program is not completed, the tentative schedule is as follows:

Monday, May 12, 9 a.m.: *Propulsion I* (Bldg. 33)—"Status of Solid Rockets," Dr. Ritchie, Thiokol Chemical Company; "Status of Liquid Rockets," Chandler C. Ross, Manager, Liquid Engine Division, Aerojet-General Corporation; "Status of Ramjets and Future Possibilities," by Dr. W. Avery, Johns Hopkins Applied Physics Laboratory; and "Novel Propulsion Systems," by Wolfgang E. Moeckel, Assistant Chief, Supersonic Propulsion Division, NACA Lewis Laboratory.

Guidance and Control I (Bldg. 102)—"Effect of Wind and Temperature Gradients on Design of Missile Flight Control Systems," M. W. Lifson, Chance Vought Aircraft; "Mixed Guidance," by James W. Follin, Jr., Johns Hopkins Applied Physics Laboratory; "Guidance Schemes for Intercepting Re-Entry Bodies," Stanley D. Hayes, Convair, A Division of General Dynamics Corporation; "Advanced Instrumentation Concepts in the Field of Inertial Navigation," H. Schlitt, Bell Aircraft.

Monday, May 12, 2 p.m.: *Propulsion II* (Bldg. 33)—Panel discussion, Dr. Zucrow, Moderator; participants—Dr. Ritchie, Mr. Ross, Dr. Avery, and Mr. Moeckel.

Guidance and Control II (Bldg. 102)—"Effects of Gyroscopic Cross Coupling on Missile Automatic Flight Control Systems," J. G. McCracken, Chance Vought; "Airborne Digital Computers for Ballistic Missile Guidance," W. T. Chow, American Bosch Arma Corporation; "Vanguard Guidance," Leonard T. Arnowitz, The Martin Company; "The Effects of Guidance Beam Wander on the Design of a Missile Beam-Riding Computer," J. R. Burton and J. M. Tucker, McDonnell Aircraft.

Tuesday, May 13, 9 a.m.: *Engineering Management in Missile Development* (Bldg. 33)—Papers by William Purdy, The Martin Company, and Don Patterson, Department of Defense; "Organizing to Develop the ICBM Nose Cone," H. W. Page, General Electric Company;

Vernon Outman
Meeting Chairman

"Military-Industrial Missile Systems Management Relationship," V. H. Zabriskie, Bell Aircraft.

Operational Analysis (Bldg. 102)—Papers by Abe Hyatt and V. Bieber, Navy Bureau of Aeronautics, and Charles Meyer, Johns Hopkins Applied Physics Laboratory; "Operational Research as a Method of Communications," W. F. Whitmore, U.S. Navy Fleet Ballistic Missile Program; a paper by Wallace Helmuth, The Martin Company.

Tuesday, May 13, 2 p.m.: *Aerodynamics and Ballistics* (Bldg. 33)—Paper by Antonio Ferri, Polytechnic Institute of Brooklyn; "Re-Entry and Recovery of Satellites Initially in Circular Orbit About the Earth," A. J. Eggers and Mr. Wong, NACA Ames Aeronautical Laboratory; paper by S. M. Bogdonoff, Princeton University; "NACA Hypersonic Flight Testing With Multistage Rockets," J. A. Shortal, and A. G. Swanson, NACA Langley Laboratory.

Composite Design (Bldg. 102)—"Program for Improvement of Reliability of Missile Power Supplies," by Mr. Amster, The Ramo-Wooldridge Corp.; "Quantitative Results of the Regulus I Reliability Program," Mr. Seldon, Chance Vought; "Missile Design for Shipboard Operation," J. Floyd, Johns Hopkins Applied Physics Laboratory.

Wednesday, May 14, 9 a.m.: *Astronautics* (Bldg. 33)—"High Performance Electric Propulsion System," G. M. Giannini and Rolf Buehler, G. M. Giannini & Co., Inc.; "Techniques for Departure and Return in Interplanetary Flight," K. J. Bossart, Convair Astronautics; "Some Aspects of Recoverable

Re-Entry," J. S. Isenberg, Bell Aircraft; "Space Navigation Between Nearby Planets by Optical Resection and Inertial Systems," J. Carroll, American Bosch Arma.

Structures and Aerodynamic Heating (Bldg. 102)—"Re-Entry Nose Cone," Lloyd Wilson, Lockheed Aircraft Corporation; "Aerodynamic Heating Facilities," John Wild, ARO, Inc.; "Atlas Structure," R. S. Shorey, Convair Astronautics; and Arthur Schnitt, Bell Aircraft.

Necrology

Charles F. Brooks

News of the death on January 8 of Charles F. Brooks (AF), Emeritus Professor of Meteorology, Harvard University, has reached the Institute. He was 66.

Former Director of Harvard's Blue Hill Meteorological Observatory, Professor Brooks had been Secretary of the American Meteorological Society. He also was a member of the Royal Meteorological Society, American Association for the Advancement of Science, Association of American Geographers, American Geographical Association, and American Geophysical Union.

He collaborated on *The Effect of Wind and Other Weather Conditions on the Flight of Airplanes*, wrote *Why Weather?* in 1924, and was Editor of the AMS Bulletin.

He became an IAS member on January 9, 1933.

Charles C. Clark

The Institute has received word of the death of Charles C. Clark (AF), meteorologist and lawyer of Chevy Chase, Md. Dr. Clark had worked in aeronautical and airways weather service and practiced law with reference to aviation.

He received his education at Temple and Columbia Universities and was a member of the American Meteorological Society.

Arthur J. Rowledge

The Institute has learned of the death of Arthur J. Rowledge, an IAS Fellow and Founder Member, on December 12 at his home in Derby, England.

Mr. Rowledge had been Chief Assistant Engineer for Rolls-Royce Ltd. He was a Fellow of the Royal Aeronautical Society.

Sir Alliot Verdon-Roe

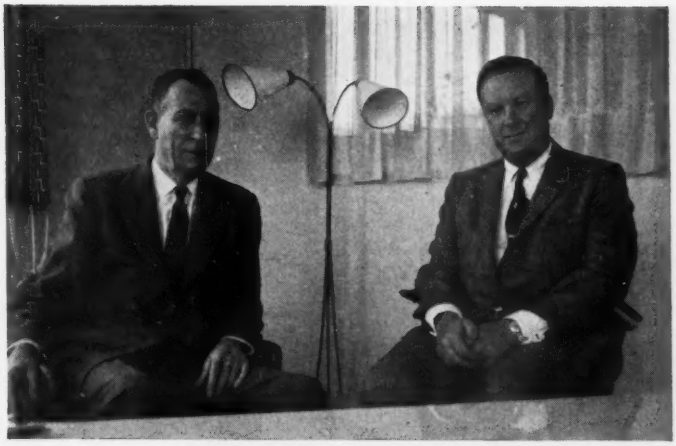
The Institute notes with sadness the death of Sir Alliot Verdon-Roe, an IAS Fellow, on January 5 at Portsmouth, England. He was 80.

Sir Alliot was the first Englishman to fly a heavier-than-air plane over British soil, on June 8, 1906. One of Britain's greatest aviation pioneers, he founded A. V. Roe Co., Ltd. in partnership with his brother Humphrey in 1909. He built the first enclosed aircraft, a monoplane, in 1912 and the first seaplane to fly in England. One of his early experimental aircraft, the Bull's Eye, was a 9-hp. engine triplane which had several successful flights of 300 yards. These still stand as records for low-powered flying.

His company turned out the Avro or "504" warplane at the beginning of World War I, the aircraft which brought down the first Zeppelin of the war and carried out a historic raid on the Zeppelin Works at Friedrichshafen.

Sir Alliot sold his interest in A. V. Roe in 1928 to buy into S. E. Saunders, Ltd. The firm became Saunders-Roe, Ltd. with Sir Alliot as Chairman and Joint Managing Director. As early as 1928 he was actively engaged in designing an aircraft to fly at the unheard of speed of 1,000 m.p.h.

Sir Alliot was a graduate of St. Paul's School, London, and King's College (Engineering Side), Strand, London. A marine engineer, he spent a year in the United States and Canada, from 1892 to 1893.



A. T. Mattson (AF) spoke on "The Role of Aeronautical Research in the Design of Airplanes" at the Training Center for Experimental Aerodynamics, Rhode-Saint-Genese, Belgium, on February 20. Mr. Mattson *(right)* is Chief, Transonic Wind Tunnel Branch, NACA Langley Aeronautical Laboratory. The talk summarized, in a general way, research developments in fields of performance, jet propulsion, stability and control, flutter, and buffeting. The Training Center, headed by R. P. Harrington (AF) *(left)*, was founded in 1956 as an aid to NATO countries.

Telemetering Conference In Baltimore June 2–4

Telemetering applied to interplanetary vehicles and cosmic-ray and rocket-sounding studies will be discussed at the National Telemetering Conference, June 2–4, at the Lord Baltimore Hotel, Baltimore, Md.

Sponsored by the ISA, ARS, AIEE, and IAS, the meeting has scheduled sessions on the application of transistors to telemetering, R. F. receiver design, accuracy analysis, reliability, evaluation of pick-ups, and data reduction.

The technical program will include a program on IGY which deals not only with radio and wired telemetering, but also a new medium of transmission, sonic telemetering. Other papers dealing with oceanography, astronomy, frequency allocation, and industrial applications will be read.

Leading manufacturers in the telemetering field will show and demonstrate latest equipment, and a number of field trips have been planned.

On June 5, a day after the meeting officially ends, a classified session has been planned. Some papers from Switzerland, England, France, and Italy will be presented. A banquet has been scheduled for Tuesday evening, June 3.

Princeton Names Building After Daniel C. Sayre

A Fellow of the Institute who died 2 years ago has been honored by Princeton University. The late Daniel Clemens Sayre's name has been given to the aeronautical sciences headquarters building at Princeton's James Forrestal Research Center. The building has been officially named Sayre Hall.

Professor Sayre organized the school's Department of Aeronautical Engineering in 1941. Later, he was made first Director of the Forrestal Center. At his death at 53, he was combining this directorship with duties as Associate Dean, School of Engineering.

A plaque memorializing Professor Sayre has been placed in the main entrance to the building. It recalls his achievement as first Chairman of the Department of Aeronautical Engineering and his guidance in the establishment of the Center.

Three-story Sayre Hall houses the Center administrative offices, graduate classrooms, and research projects.

Six IAS Members on NACA Space Committee

The recently formed NACA special committee on space technology includes six members of the Institute out of the 14 men who comprise the committee. Five of these members are IAS Fellows.

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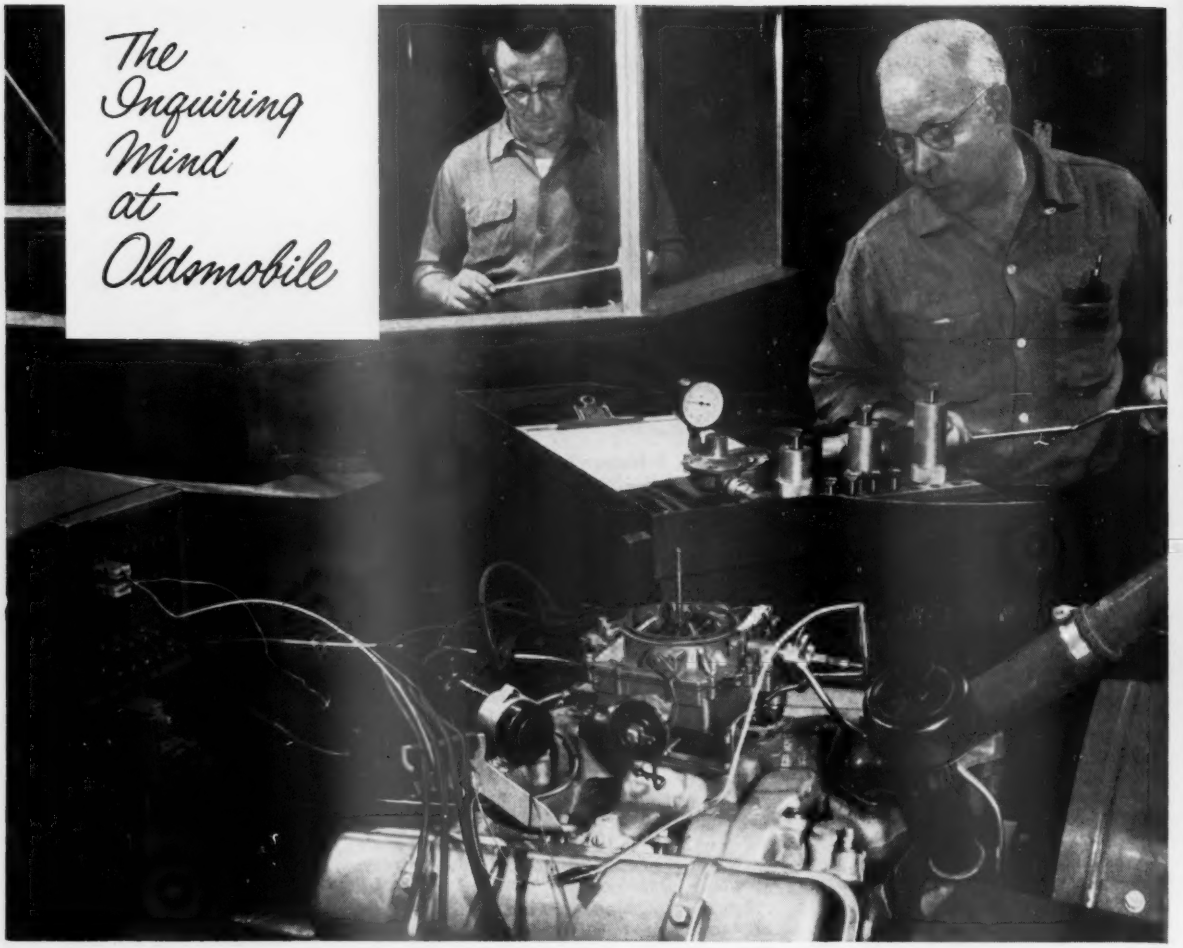
The Inquiring Mind at Oldsmobile



no. 2 OF A SERIES

IT "WORKS" WHILE IT WHISTLES

Advanced sonic testing techniques are used to make precision measurements that determine an engine's compression ratio.

To Olds engineers, compression ratio is a direct measure of the engine's thermodynamic efficiency; the higher the compression ratio, the more energy utilized from the fuel. But with higher compression ratios, engineers needed to know whether cylinder heads and combustion chambers were accurate during initial engine development. To meet this challenge, Oldsmobile engineers and General Motors Research developed a simple, yet extremely accurate measuring device commonly called the "whistle checker".

Based on the principle of resonance, the known volume of air in the "whistle checker" is placed in resonance with the unknown volume of air in the combustion chamber. A reading of the micrometer adjusting screw of the "whistle checker" is easily translated into cubic centimeters and is accurate to .2 cc. What is just as important, this instrument can tell if there is any loss of compression due to leakage past the piston rings.

In many ways and in many directions the Inquiring Mind at Oldsmobile is constantly probing, constantly seeking new and better ways to build the finest automobiles in the industry. Try a '58 Oldsmobile on the road. You'll discover the difference for yourself.

OLDSMOBILE DIVISION, GENERAL MOTORS CORP.

OLDSMOBILE

Pioneer in Progressive Engineering ...Famous for Quality Manufacturing

Besides H. Guyford Stever, 1958 IAS Vice-President, who heads the committee, the following Institute members are on it: H. Julian Allen, Chief, High Speed Research Division, NACA, Ames; Milton U. Clauser, Director, Aeronautical Research Lab., The Ramo-Wooldridge Corporation; Robert Gilruth (AF), Assistant Director, NACA, Langley; W. Randolph Lovelace, II, M.D., Chief, Surgical Section, Lovelace Clinic, and Director, Lovelace Foundation for Medical Education and Research; and Abe Silverstein, Associate Director, NACA, Lewis.

A Rhymed Thank You Read by Hunsaker

Verses by Dudley Clapp of Massachusetts Institute of Technology were read by Professor Jerome C. Hunsaker at the Honors Night Dinner after he was presented the Royal Aeronautical Society Gold Medal. This novel speech of acceptance was read to Sir George Edwards, 1957 RAeS President, who presented the Medal to Professor Hunsaker.

More than anyone can measure
I my keen appreciation
And my overwhelming pleasure
At receiving such a treasure
As this medal and citation
From our well-loved allied nation.

Research problems aeronautic,
When I started to pursue them,
Were considered quite exotic
And pursuit of them quixotic,
But a few of us stuck to them
Finding out a way to do them.

With these problems multiplying,
I was designated Chairman
Of a group to study flying:
Seven thousand workers vying
With your own to help our airmen,
All our dedicated airmen.

Your Society decided
Thus to honor my position
Not alone for work that I did;
The devoted men I guided
Really won this recognition
In accomplishing our mission.

Sir George, I thank you most sincerely.
This unique and priceless token
I shall cherish very dearly,
All the more because it clearly
Is a pledge most firmly spoken
That our ties shall not be broken.

W. Laurence LePage (AF), an aeronautical engineer and management consultant, has been elected President of The Franklin Institute. He has had a life-long interest in aviation and aeronautical research, especially in rotary wing aircraft.

NEWS OF MEMBERS

▸ **Major Gen. Albert Boyd, USAF (Ret.)** (F), has been elected a Vice-President of the Westinghouse Electric Corporation and General Manager, defense products divisions.

▸ **C. A. Frische** (AF), formerly Executive Vice-President, Sperry Gyroscope Company, a Division of Sperry Rand Corporation, has been named President of Sperry.

▸ **Barry Griffith King** (M), Ph.D., has been named Vice-President, Life Sciences, Operations Research Incorporated, Silver Spring, Md. Dr. King formerly was the Research Executive, Medical Division, CAA.

▸ **George C. Martin** (F) has been elected a Vice-President of Boeing Airplane Company. Formerly Chief Engineer, Seattle Division, Mr. Martin also became General Manager of the division.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Robert A. Fuhrman (AF), formerly Chief, Technical Section, Ryan Aeronautical Company, has joined the Lockheed Missile Systems Division as Technical Staff Head, Systems Integration Department. Mr. Fuhrman was Vice-Chairman of the IAS San Diego Section.

Martin Goland (AF) has been appointed Director of the Southwest Research Institute. He had been a Vice-President of the Institute since 1955 and also is Director of Research, Kellert Aircraft Corporation.

Comdr. H. J. Huester, USNR (AF), formerly Deputy Director, Aeronautical Structures Laboratory, NAMATCEN, Philadelphia, Pa., is now with Consulting & Technical Services, Arlington, Va.

Felix A. Kalinski (M) has been elected Vice-President of Vertol Aircraft Corporation to coordinate and direct activities of the contracts, customer relations, and engineering divisions. He will continue his current job as Assistant to the President, in charge of long-range planning.

John Dill McKenny (A) has been appointed Principal Engineer, Research and Development Section, at Clary Dynamics, the aircraft and automatic controls division of Clary Corporation, San Gabriel, Calif. Mr. McKenny is former Section Chief, Mechanical Systems Engineering, Jet Propulsion Laboratory, California Institute of Technology, and did not occupy the position incorrectly identified with him in these columns in the REVIEW for January.

Karl Arnstein (F), Consultant and retired Vice-President in charge of Engineering, Goodyear Aircraft Corporation, was honored by the Navy recently when it bestowed upon him the Distinguished Public Service Award. The Navy's highest civilian honor, pinned on his jacket by Fred A. Bantz, Assistant Secretary of the Navy, Materiel, was awarded for Dr. Arnstein's outstanding contribution to the Navy Department in the fields of scientific research and development. The 70-year-old scientist is one of the world's foremost designers of lighter-than-air craft.

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N. C. Schnaubelt (A), formerly Supervisor, Contract Service, Solar Aircraft Company, has been promoted to Sales Representative, Southwest District.

Edward A. Speakman (AF), former Vice-President and General Manager, Fairchild Engine and Airplane Corporation's Guided Missiles Division, has been named to the newly created post of Manager, Planning for Defense Electronic Products, Radio Corporation of America.

Theodore K. Steele (M) has been appointed Vice-President, Research and Engineering, Bulova Research and Development Laboratories, Inc. Dr. Steele formerly was Director, Research and Engineering for Bulova.

A. R. Teasdale (M) has been named to the newly created post of Director, Advanced Technology, Temco Aircraft Corporation. He had been Temco Chief of Avionics.

H. W. Withington (M), formerly Senior Project Engineer, Seattle Division, Boeing Airplane Company, has been named Chief Engineer of the division.

Claude Witze (A), Military Editor of *Aviation Week* magazine for the past 4 years, has joined the staff of *Air Force Magazine* as Senior Editor.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation** reports that it has developed large solid propellant rocket motors for the Polaris propulsion system. Six Aerojet scientists have been named to various NACA committees and subcommittees: Chandler C. Ross, Vice-President, Engineering—aircraft power plants; Richard D. Geckler, Manager, Solid Rocket Plant—engine performance and operation; Rear Adm. R. S. Hatcher, USN (Ret.), Advanced Planning Group—seaplanes; Gordon Banerian, Manager, TurboMachinery Division—compressors and turbines; Yuan C. Lee, Director, Research and Planning—combustion; and A. W. Cobb, Sr., Engineer, Facilities Coordinator—aircraft noise. The firm's Northeastern District Office has moved to 821 Franklin Avenue, Garden City, L.I., N.Y.

• **Aluminum Company of America** has announced plans for new facilities at the firm's Cressona (Pa.) works, including installation of a vertical impact extrusion press and equipment to produce sheathing for conductor and coaxial cables.

• **American Airlines, Inc.,** reports Herbert D. Baker has joined the firm as Director, Maintenance Planning and Facilities, at its Tulsa overhaul base. Allan A. Harris has joined the firm as Director, Aircraft Sales, at the firm's General Offices, New York City.

• **Bell Aircraft Corporation** has announced that all Buffalo and Niagara Frontier defense products activities will be operated by a new autonomous unit to be known as the Niagara Frontier Division. Ray P. Whitman, First Vice-President of Bell, will be General Manager of the new division. Vice-President Roy J. Sandstrom has been assigned to plan and direct all satellite and space travel projects.

• **Bendix Aviation Corporation,** Products Division, has announced the appointments of D. M. Heller and R. E. Whiffen as Assistant General Managers, and W. P. Bollinger as Director, Engineering, Missile Section. Sidney D. Hammarlund and Martin S. Weishaar have been appointed Assistant Sales Manager, Contracts and Administration, and Assistant Sales Manager, Customer Relations, in the division. William J. Kunz, Jr., has been named Engineering Manager, Aircraft Engine

(*Continued on page 63*)

The second production model of Boeing Airplane Company's 707 is shown with the blue and white colors of its future owner, Pan American World Airways, Inc., which has ordered six Model 707-120 Jet Stratoliners and 17 larger 707-320 Intercontinentals. Boeing reports a total of 162 jet transport orders in hand.

Aircraft Nuclear Propulsion at Marquardt

by
Roy E. Marquardt
President

Aircraft Nuclear Propulsion projects now underway in ASTRO, a Division of Marquardt Aircraft, offer engineers and scientists challenging opportunities in a variety of technical fields. Here, where we are dealing with development problems on high-performance systems with stringent design and reliability requirements, creative engineers and scientists will find real challenge and opportunity for accomplishment.

Project personnel are currently working in such fields as radiation shield design, aerothermodynamics, control system design, instrumentation research, stress analysis, and neutronics. Problems range in scope from preliminary performance analysis through design of test facilities.

Experienced engineers and scientists capable of making contributions in these and related fields are invited to investigate the employment opportunities at Marquardt. You will find a combination of significant, active projects and a lively interest in new ideas, creating the environment for professional growth. Please address your inquiries to Jim Dale, Professional Personnel, 16555 Saticoy Street, Van Nuys, California.

Roy E Marquardt

marquardt AIRCRAFT CO.
VAN NUYS, CALIFORNIA OGDEN, UTAH

DATELINE world

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

26,464-Lb. Payload Lifted to 7,980 Ft. by U.S.S.R. 'Copter

◆ Late last October the Soviet Mi-6 helicopter, in a record-seeking flight, allegedly lifted a 26,464-lb. payload to 7,980 ft. At the same time, the designer, Dr. Mikhail Leontovich Mil, announced in a press conference that the Mi-6 can carry 70 to 80 passengers and released some design details for publication.

Dr. Mil said that the Mi-6 is equipped with two turboprop engines, designed by Pavel Aleksandrovich Solov'yev, and he described this engine model as having dual turbines—one to rotate the compressor, and a free turbine located directly in the gas flow from the first turbine to transmit its energy to the rotor shaft through a reduction gear. This arrangement, Dr. Mil said, eliminates the necessity for a complex clutch because of the gas coupling between the two turbines.

The big helicopter has been the subject of a number of items appearing in Soviet, European, and domestic publications in recent months, with interest centering around the October load-carrying feat, which, if the released figures are fact, surpasses the previous world record established by a U.S. Marine Corps HR2S-1 (13,250 lbs. to 7,000 ft.). The Mi-6 went into the air for a record around noontime on October 30, after waiting through the morning for clear skies. The ceiling was reached in 10 min., and the helicopter was back on the ground about 14 min. later. The load, the Soviets said, was made up of "335 sealed sacks containing 12,004 kg. ballast," which consisted of river sand meticulously weighed and sealed in the sacks under supervision. With this weight, a height of 6,560 ft. had to be attained to challenge the U.S.-held record. This elevation was surpassed, according to the Soviets, and records in the sealed instruments were submitted to the FAI (Federation Aeronautique Internationale) for official recognition.

In his press conference, the proud designer boasted that the Mi-6 made its maiden flight only 10 days after the rotor had been installed and said that flight testing was completed in "a very short time." He commented that the Mi-1 and the Mi-4 had experienced trouble with "rotor flutter," but personnel from his design bureau and from the TSAGI (an aerodynamic institute) solved the problem, and the "complicated phenomena" were "eradicated" in the Mi-6 despite the great size of the rotor blades. Other vibrations, such as "ground resonance," were also avoided, he said. Dr. Gil told his interviewers that the Mi-6 has hydraulic servo-controls and that the main rotor blades reach a maximum tip speed of the order of 911 ft. per sec. The fabrication of long tubes with varying diameter and wall thickness, and the development of metal bonding to reduce the number of bolts and rivets, were cited as among the construction problems to be overcome in developing the rotor blades.

Soviets Report Fighter Is Flown to 62,700 Ft.

◆ An item in the December 27, 1957, issue of *Red Star* claims that a Soviet air force major flew a fighter to an altitude of 19,111 meters (62,700 ft.). It was further stated that the flight continued to a higher altitude and that it was not performed in an experimental aircraft but in a standard series-produced aircraft.

Top Scientist Makes Plea in U.S.S.R. Lower House for Funds

◆ In a Reuters News dispatch of December 20, 1957, a leading Soviet scientist conceded that Russia still has a long way to go to "beat the United States on all scientific fronts." Asking for more money to do the job, Alexander Nesmyanov, President of the Soviet Academy of Sciences, came before the startled lower house of the Soviet Parliament with a list of complaints and demands.

According to the Reuters release, Nesmyanov included the following comments (verbatim where indicated by quotation marks) in his address before the solons of the U.S.S.R.:

The launching of two earth satellites demonstrates the superiority of Soviet rocket techniques; and great progress has been made "in the realm of mechanics, mathematics, chemistry, radio techniques, and automation." However, "it would be harmful to overestimate our scientific achievements. Great efforts are still needed to beat the United States on all scientific fronts."

Russia has 240,000 scientists—"more than any other country"—but still more are needed "to extract the maximum from our research."

There is duplication in the work of Russian scientists, and better equipment and more money are needed. The amount allotted for research is "less than in the United States"; and industry has failed to "produce what the scientists want."

Russian scientists often have to use "antiquated equipment." West Germany has produced an electronic microscope which is better than Soviet electronic microscopes by as wide a margin as the latest Soviet jet airliner is better than an aircraft of the 1930's.

Soviet investment in science will be increased in 1958 by 10 per cent—to 18.2 billion rubles ($4,550,000,000). Still more money is needed. "Investment in science must be increased at a rate faster than other investment in the national economy." In 1954, for each individual scientist, the State provided 9,000 rubles ($2,250) worth of equipment. In 1957 this figure fell to 5,300 rubles ($1,325). "This is bad," and steps must be taken to bring the level back to at least 9,000 rubles a year per scientist.

The U.S. National Science Foundation estimates that the U.S., through government and industry, spends about five billion a year on research, but much of this outlay is on consumer products not developed in Russia.

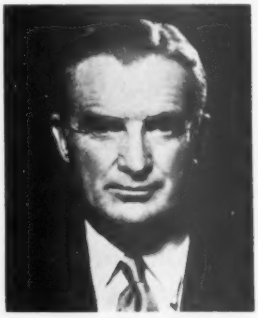
Nesmyanov's plea for more money did not go unheeded. The Soviet Parliament has been told by Finance Minister Zverev that the U.S.S.R. will spend a total of 18.2 billion rubles in 1958 on scientific research. At the official exchange rate of 4 rubles to a dollar, this is the equivalent of $4,550,000,000.

Current (1958) Soviet science research spending reportedly will increase 1.8 billion rubles ($450 million) over 1957.

Ministry of Defense appropriations for 1958 are scheduled at 96.3 billion rubles—$24,075,000,000 (96.7 billion rubles in 1957). This 1958 appropriation probably includes only part of the total spending for military purposes.

Guest Editorial

The address by the United States Senator from Missouri at the 1958 Honors Night Dinner of the Institute.



The Honorable W. Stuart Symington
United States Senator, Missouri

I want to talk briefly on the subject which is closest to the minds and hearts of all of us—national security.

Recently my wife and I were at a gay and pleasant evening, in honor of a friend's daughter. At that party, however, one of the parents said:

"I have been reading in the papers about these reports, the Gaither Report and the Rockefeller Report. If their conclusions are true, why don't we do something about it? God has given us responsibility for these children here tonight. You are in the Government. Why don't you do something about it?"

In the legislative branch, where we do not have executive prerogative, perhaps our chief contribution can be continuous effort to keep the people informed.

The greatest single power in this country to help obtain more adequate defense is an informed, and thereupon aroused, public opinion because, unlike the citizens of the lands which now threaten us, we are still the masters of our government, not its servants.

Over many years, and as late as last November 16, the leaders of the Soviet Union have emphasized the irreconcilability of Communism and capitalism—and no democratic government can live against this ever-expanding Communist aggression unless its people are given all truth which does not help the possible enemy.

The people of this country, therefore, need, and are entitled to, that truth. Without it they cannot demand—and thereby obtain—the action required.

No organization in the world is more concerned with facts than is the Institute of Aeronautical Sciences. That is why I am going to dwell on some facts—what we have done since the launching of the first Sputnik on October 4—an event well described by one of your greatest members as a "technological Pearl Harbor"—and what we should do.

In a way, Sputnik is a blessing. It has awakened many people. As example, a report of the Senate Military Preparedness Subcommittee, agreed to only last week by all Republicans and Democrats on the Committee, included the following six findings:

"On the basis of sworn testimony by top scientists, leading industrialists, and government and military officials, it can now be said:

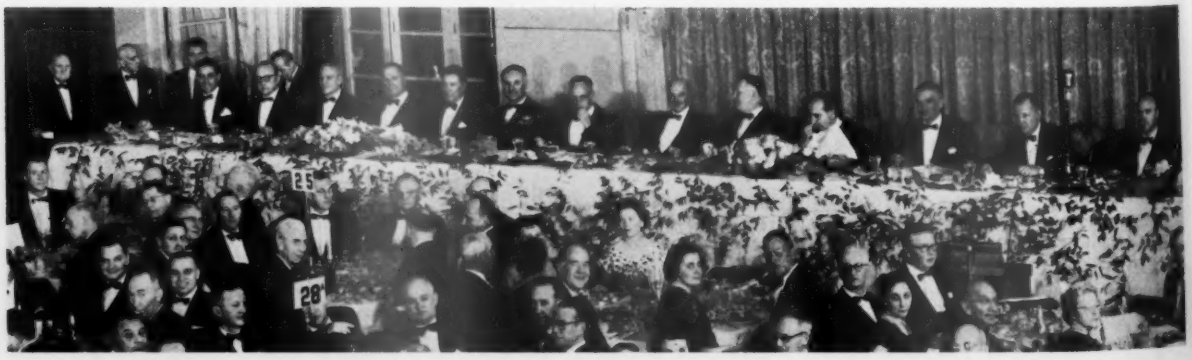
"(1) The Soviet Union leads the United States in the development of ballistic missiles.

"(2) The Soviet Union leads the United States in number of submarines, which raises the possibility of attack with modern weapons or missiles—although the indications are that we are ahead in the production of atomic submarines.

"(3) The Soviet Union is rapidly closing the gap in manned air power and, at present rates, will surpass this country in a comparatively short time.

"(4) The Soviet Union has a system which enables it to develop new weapons in substantially less time than the United States.

"(5) The Soviet Union has led the world into outer space.



"(6) The Soviet Union is producing scientists and technicians at a rate substantially greater than our country."

If anybody has any further doubts about the degree of the current danger, let him remember, as he studies these six findings, that only 12 years ago the economy of the Soviet Union was in critical condition, with much if not most of its industrial potential destroyed.

And 12 years ago the United States was far and away the strongest nation on earth, on the land, on and under the sea, and in the air.

Actually, five of these six findings have been known for a year and a half because similar sworn testimony from military and civilian experts was presented in the Air Power Subcommittee hearings of 1956.

But when the conclusions of that Subcommittee were published, there was no Sputnik to point up the findings, and people asked, "How do you expect to get anywhere criticizing the Eisenhower Administration about its plans for our national defense?"

And so at least another year was lost.

Now these events of the past are important only because of the lessons they can give us for the future. To me, the lesson in this case is clear.

We must take more prompt and more decisive steps to see that our guard is again raised to adequacy—and then be equally determined to see that it is never lowered again until the menace of Communist aggression subsides.

With those premises, what have we done since October 4—and what do we plan to do. It is clear that what we have done is inadequate—and what we plan to do is inadequate.

There has been some acceleration of the ballistic missile programs, and there has been a restoration of the cuts in Research and Development funds which were made only a few weeks before Sputnik.

There has been some step-up in plans for antisubmarine warfare capability and also some improvement in the dispersal program recommended for the Strategic Air Command.

And most important, Sputnik has prompted new discussions about a subject we started to face up to nearly 15 years ago as the result of actual war experience—but then shoved under the rug in peacetime.

I refer to efforts to clean up the incredibly complicated organization structure now characteristic of the Pentagon.

People tell us that in order to get a decision in that building, you often have to touch so many bases that it is like trying to play ten baseball games on one baseball diamond. As a result, each of the teams tries to create its own diamond in the one park. Henry Kissinger put it well when he said that each of the three Services would appear to be preparing to fight any possible future war by itself.

Not only does this Pentagon set-up result in an annual waste to the taxpayer of billions of dollars, but also the divided authority inherent in any such administrative jungle may prove fatal in an era when every minute of delay in decision could prove fatal.

Yes, there was a tremendous public reaction to Sputnik. But that reaction has not resulted in nearly enough action.

Do you doubt that statement? Then consider the following facts:

The budget decided on last year—that is, the budget for the Fiscal Year 1958—reduced Air Force funds nearly $1 billion lower than the appropriation for the previous year, 1957.

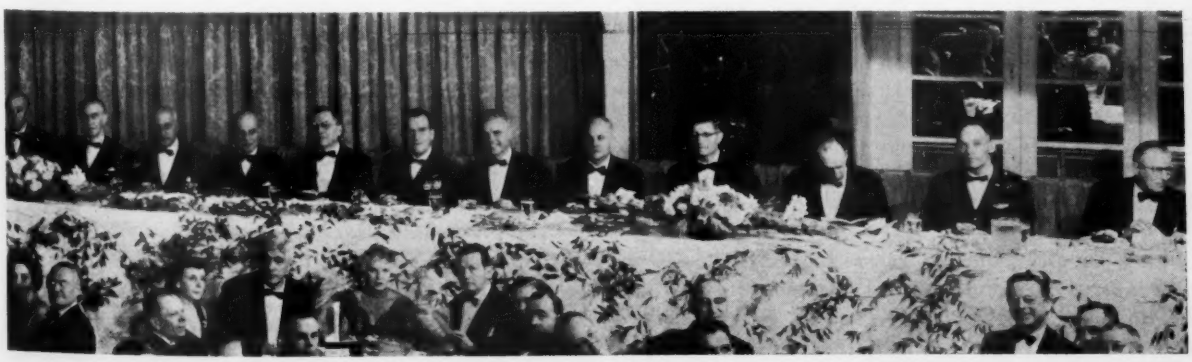
The 1958 supplemental budget, compiled after Sputnik, largely replaced the amount of the 1957 reduction, but added nothing else.

This 1958 supplemental budget does not contain one cent for aircraft procurement, Air Force or Navy.

The budget for this year, the Fiscal Year 1959, presented to the Congress earlier this month, gives the Air Force an increase of less than 2 per cent, not even enough to cover the lessened value of the dollar—and this despite recent sworn testimony before the Senate Preparedness Subcommittee that we are many hundreds of planes short of the absolute minimum requirement for adequate national defense.

And despite the President's heavy reliance on the deterrent capacity of SAC, made in his two speeches after the launching of Sputnik, the heavy reductions made last April in the schedules of modern bombers and aerial jet tankers have not been restored, even though it was freely admitted that they were made to conform to the "rigid" expenditure ceiling placed on our defense at that time.

We have been channeling into defense preparedness



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a continuously decreasing percentage of our gross national product. This can only mean that we are answering the growing Communist threat by devoting more and more of our energies to the complacency of consumer comforts.

Perhaps most astounding of all, the new overall budget presented to the Congress by the President earlier this month is nearly $2 billion less—to be exact, $1 billion, 912 million—than last year's budget.

Somebody is fooling somebody—and the biggest fool of all is the fool who fools himself.

Perhaps the explanation for this continued complacency lies in a poem published only last month in an editorial on defense in *Life* magazine—a poem which had to do with what our children are being taught in school:

> "We are the biggest, we are the best.
> We are ahead of all the rest."

Perhaps you have read a book published by the Hoover Library of Palo Alto, entitled *Russia's Academy of Sciences*. How many people know that that Academy in Moscow was functioning aggressively in scientific research a great many years before the Government of the United States was formed?

In the same issue of *Life* magazine was an article, "First Hard Facts on All Russian Sciences," and it said in part:

"The entire Soviet educational system is geared to discover and develop potential scientists. . . .

"In its hundreds of thousands of trained technicians, Russia is producing men and women who know how to operate uranium mines, to build and run power plants, to do laboratory work, to put science to practical use.

"Within a generation the Soviet Union will have an enormous pool of such technicians, far more than she needs domestically, who can be used as a living export commodity.

"Sent into Africa, India, Indonesia, they may develop these areas according to the Communist scheme while the U.S., still talking bravely about free enterprise and Point Four, declines.

"It is this prospect, in addition to the purely military implications, that Americans may consider as they watch the Sputniks tumbling through the cool twilight over their secure and perhaps still somnolent country."

So there we have it. Leaders of the Soviet Union making every effort to produce hundreds of thousands of trained people like yourselves, but people who will be working for that conspiracy which is dedicated to the destruction of freedom.

What then should we do?

Whatever we do should be done promptly and decisively.

We must organize ourselves and expend much more in the integrated use of talents and facilities available to this nation by the sciences you represent.

We must take a balanced approach in moving out into space, first with unmanned, later with manned, systems, both for our national defense and our national progress.

We must wait no longer, as the days and weeks and months tick away and the Soviet Union intensifies its all-out preparations for ultimate world conquest.

We must start this winter. Already too much priceless time has been lost.

We must stop milling around, and go to work with bold vision.

We should remember the last stanza of a poem written by a great airman:

> "The shadows of wings are like wind on the wheat
> When dawn on the prairie is grey,
> And motors are droning a Requiem Mass
> For hopes that are dying today.
> Look up, my proud people, where destiny rides
> Lest lethargy make you a slave,
> And prophets go down to the tomb to inquire
> Of wisdom that lies in the grave."

That poem was not written recently. It was written over 30 years ago, by Gill Robb Wilson, in defense of Gen. Billy Mitchell.

Over 15 years after its publication, America was forced into World War II—and we still had time to mobilize; and the Free World was thereupon saved from the tyranny which again threatens us tonight.

But tonight there is so little time.

So let us first take every step possible to become informed, and then pass the word on to friends and neighbors, in the interest of adequate national defense.

I am one who agrees completely with elder statesman B. M. Baruch when he says he will never agree that his country cannot afford to do as much to defend its freedoms as any other country is doing to destroy those freedoms.

Let us follow that advice. Let us have less talk and more action—and become strong in order that we can remain free.

✦ ✦ ✦

"... *We are living in a space*
whose structure we can never grasp
or understand."

The Structure of Our Space

V. Hlavatý
Indiana University

WE ARE three-dimensional beings living in a space which we visualize as having three dimensions. We can understand and visualize properties of objects which have less than three dimensions: we speak about straight lines, curves, planes, and surfaces embedded in our three-dimensional space. We cannot understand or visualize four-dimensiona! space in which our three-dimensional space could be embedded. Hence, we cannot judge whether our three-dimensional space is a kind of a "three-dimensional plane" or whether it is a "three-dimensional surface." If you have some difficulty in grasping the meaning of the previous sentence, imagine some hypothetical two-dimensional creatures living either on a plane or on a surface. Assume that they can no more visualize or understand a three-dimensional space in which their two-dimensional "world" is embedded than we can visualize or understand a four-dimensional space with a three-dimensional world embedded in it. They cannot therefore decide whether the two-dimensional space they are living in is a plane or a surface. We could, of course, decide it for them quite easily because we visualize the three-dimensional space in which their plane (or surface) is embedded. As far as our experience about our own space is concerned, we are in a similar predicament whenever we want to determine the shape of the three-dimensional space which we occupy. We cannot, so to speak, look on our space from the outside; we must therefore base our determination of the shape of the space on "internal" information obtained by experiments performed "in" the space.

This article is concerned with the description of the main features of this endeavor. Despite the fact that the problem of the structure of our space is 2,000 years old and that we have used different approaches in looking for its solution, a definite answer has yet to be found.

Before starting to look at our problem, let us dispose of two very reasonable objections. First, one could argue that the structure of our space should be revealed to us by our intuition which tells us that space is a kind of "three-dimensional plane" (flat) rather than a "three-dimensional surface" (curved). The answer to this objection is that we simply cannot rely on our intuition. There is an almost endless list of instances in mathematics where our intuition deceives us.

The second objection may be formulated as follows: The experience of our daily life tells us that our space is flat, therefore it must be flat. This objection may be disposed of quickly by remembering that it was precisely the experience of daily life which constituted sufficient proof to our ancestors for their firm belief that the earth was flat.

We shall see that science developed two ways of attacking the problem of the structure of our space. One way could be labeled "geometry"; the other would have the more modern label of "relativity."

Prepared by Dr. Hlavatý exclusively for the *Review* as a greatly condensed version of his address on "The Structure of Space in Which We Live and Gravity" given before the IAS Indianapolis Section, October 11, 1957. The author wishes to state that certain analogies and definitions are brief because of space limitations.

Dr. Hlavatý is Professor of Mathematics and a member of the Graduate Institute for Mathematics and Mechanics.

Geometry

The geometry we are taught in our schools and which we apply to our daily life is based on the intuition and the common sense of the experiences of our daily lives. Our intuition, as well as our common sense, takes some elementary propositions for granted. Thus, for instance, we take for granted that two different points define only one straight line incident with them. Such elementary statements taken for granted without proof are called axioms. They can be neither proved nor disproved. The first to state explicitly the axioms on which our elementary geometry is based was Euclid. Geometry based on these axioms is called Euclidean geometry. It is *the* geometry we are taught in schools. Among Euclid's axioms there is one, known as Euclid's fifth, which we shall state here in a form equivalent to this axiom: "Through a point A not incident with a line b, there is only one line parallel to b."

Stated in this form, the fifth axiom tells us in fact something about the behavior of space at infinity (by definition two parallel lines intersect at a point at infinity). Therefore it is quite understandable that many mathematicians after Euclid tried to prove this axiom. The reason behind such an attempt is clear: The fifth axiom is an abstraction of our experience. If it could be proved—and not only taken for granted—we could acquire some knowledge about the behavior of our space at infinity.

There is an impressive number of "proofs" of the fifth axiom. These proofs may be grouped into three classes. In the first class are the proofs which are wrong, and therefore we shall not deal with them. In the second class are the proofs whose structure may be reduced to the following pattern of a tautology: "If **A** holds, then **A** holds." In other words, authors of such proofs proved only what they assumed. Thus, for instance, Poseidonius (first century B.C.) proved the fifth axiom by using the following definition of parallel lines: "Two straight lines a, b are parallel if the distance of a point A on a from b is independent of the choice of A on a." Using this definition he proved the fifth axiom. We know nowadays that this definition is equivalent to the fifth axiom.

The most interesting group of proofs is the third, which contains the proofs based on absurdity (*reductio ad absurdum*). In such a proof, one assumes that the fifth axiom is not valid, and one tries to deduce from this assumption a contradiction. The proofs of Saccheri (1667–1733) and Legendre (1752–1833) are of this nature. Both derived conclusions which, it seemed to them, contradicted our intuition and our common sense. Therefore—leaving the safe field of mathematical reasoning—both looked at those conclusions as contradictions and consequently claimed to have proved the fifth axiom. What they discovered and refuted were in reality some propositions of the so-called non-Euclidean geometry.

This new geometry was initiated by Lobachevski and Bolyai 130 years ago. Their leading idea may be expressed as follows: "The failure in proving the fifth axiom is probably due to the fact that this axiom cannot be proved at all. If this is true, then it must be possible to prove that the fifth axiom cannot be proved."

In order to accomplish this task they based their considerations (independently of each other) on all of Euclid's axioms with the exception of the fifth, replacing it by another axiom which contradicted the fifth. They constructed in this manner a new geometry, which came to be known as non-Euclidean geometry. They derived a set of propositions based on the new axioms. In order to be able to call this set of propositions a "geometry," it was necessary to prove that their "new" fifth axiom was compatible with the remaining ones. We shall see that Lobachevski tried to prove it (while Bolyai did not) and failed. However, they both derived a set of interesting formulas from their axioms and showed at least that this set could be used as a workable basis.

The axiom with which they replaced Euclid's fifth axiom stands in direct contradiction to it: "Through a point A not incident with a line b, there are two parallel lines to b." Your reaction to this requirement is probably the same as was the reaction of many learned men in Lobachevski's time. You certainly cannot be blamed if you reject any attempt to take this axiom seriously because it outrageously contradicts our intuition.

Lobachevski was aware of this fact and answered his opponents in a very sophisticated way. According to him, the new geometry contained two classes of statements and formulas. The first class consisted of results which are the same as those in Euclidean geometry. (For instance, a circle is defined by three points and has a unique center.) Before we discuss the contents of the second class, let me first draw an analogy. For spherical trigonometry, as taught in our schools, there are also two classes of results. The results of one class are the same as in Euclidean geometry. The results of the other class contain the radius r of the sphere. These results have the property that they are valid for any $r \neq 0$ and in particular, if r is very large, then these formulas approach the corresponding formulas of Euclidean geometry.

This situation repeats itself in the non-Euclidean geometry. The results and formulas of the second class contain an arbitrary constant C which cannot be determined by the theory. If $1/C$ is very small, then these results approach the corresponding results of Euclidean geometry. Thus, for instance, the angle α of the two parallels which can be drawn to a line through a point A is a function of C, $\alpha = \alpha(C)$ such that for $1/C \to 0$ we have $\alpha \to \pi$.

The conclusion drawn by Lobachevski from this fact was ingenious: If our space is described by the axioms of the new geometry, then its curvature—i.e., the number $1/C$— is so small that it cannot be detected in our daily life. Thus, for instance, the two parallels to a line, which are mentioned in his new axioms, make an angle so close to π that the difference from π cannot be detected by our daily life experience. This could

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be formulated in a slightly different way: If the space has a curvature $1/C \neq 0$, then the constant C is very large compared with the measurements of our daily life.

This observation led him to an attempt to prove the compatibility of his new axiom with the remaining ones he used. He sought to achieve his proof by finding experimentally the curvature $1/C$ of our space. It was clear to him that he must use for this purpose a measurement on astronomical scale because measurement on terrestrial scale is "too small" compared with the constant C which he wanted to find. Therefore he measured the triangle whose vertices were the sun, the earth, and Sirius. Substituting the observed data into his formulas which contained C, he was able to find its value $C > 166{,}320\,r$, where r is the distance of the earth from the sun. Therefore he could claim that his axioms really described the structure of the space in which we are living and, therefore, were compatible with each other. Moreover, he found the upper bound for the curvature $1/C$ of space. According to his results, the curvature is different from zero but is so small that for all practical purposes of our daily life it must be considered to be equal to zero.

Unfortunately, God does not reveal to us so simply the mysteries of His creation. Later on it was found that the value $1/C$ detected by Lobachevski was within the limits of permissible experimental errors inherent to measuring instruments. Therefore the right evaluation of Lobachevski's result was that space is either flat $(1/C = 0)$—i.e., Euclidean—or curved $(1/C \neq 0)$; but it could not be decided on the basis of Lobachevski's measurement which of these two statements was true. Of course, if $1/C = 0$ then Euclid's fifth axiom is in force, while for $1/C \neq 0$ the non-Euclidean Lobachevski-Bolyai axioms describe the structure of our space. However, no choice was possible between these two possibilities.

Thus ended the first chapter of the 2,000-year struggle between man and God for the mystery of space. The result: Failure.

Interlude

This failure turned out to be very fruitful for it led to developments which opened new and unexpected horizons in scientific thinking.

Lobachevski did not prove the compatibility of his axioms. Although the non-Euclidean geometry—i.e., the set of results based on the new axioms—did not reveal any internal logical contradiction (even though there seemed to be some external contradiction with our intuition), it was not clear whether future investigation of these new axioms would not lead eventually to some contradiction. We know from metamathematics that it is not possible to prove the compatibility of a set of axioms. What could be proved is that a set of axioms is compatible to the same extent as a set of axioms belonging to another branch of mathematics.

The reason for the failure of geometry to solve the problem connected with the fifth axiom was clearly stated by d'Alembert. In his article "Parallèles" (*Encyclopedie Méthodique Mathématique*, II 519) he wrote: "La définition et les propriétés de la ligne droite, ainsi que des lignes parallèles sont l'écueil et pour ainsi dire le scandale des éléments de Géométrie."* In what follows we shall see the importance of this remark.

Working on a completely different problem, Beltrami (1835–1900) found that the Lobachevski-Bolyai axioms were satisfied on every surface with constant negative curvature† provided that the term "straight line" can be replaced by the terms " 'shortest line' between two points."‡ The significance of this discovery is of paramount importance in the problem of the determination of the structure of space. It shows that the Lobachevski-Bolyai axioms are compatible to the same extent as Euclid's axioms. Indeed, the existence of a surface (of constant negative curvature) in Euclidean space requires the fulfillment of Euclid's axioms. It shows also that all previous attempts to prove Euclid's fifth axiom must either be wrong or must be reducible to a tautology; the fifth axiom cannot be proved simply because a counterexample had been exhibited. There are indeed spaces—i.e., two-dimensional surfaces of constant negative curvature—for which the fifth axiom does not hold. It cannot be disproved either, for there are spaces—e.g., the Euclidean plane—for which it holds. Beltrami's result finally also shows that a set of axioms which we use as the basis for a geometry is an act of our own free volition, completely independent of the space in which we happen to live. If we choose Euclid's axioms, we obtain a geometry of a space which is quite different from the geometry of a space in which the Lobachevski-Bolyai axioms are satisfied. Neither one of these spaces is necessarily the true representation of the space in which we live.

Having found at least one instance where Euclidean axioms are not valid, we cannot eliminate the possibility of a space for which neither Euclid's nor the Lobachevski-Bolyai axioms hold. Our problem must therefore be enlarged and redefined. There is no question any longer of the validity of Euclid's axioms in our space. We have to admit that our space is governed by a set of axioms which we do not know a priori and which it remains for us to discover. It means essentially that, in our struggle for the understanding of the structure of space, we are led to reformulate our basic question: We must not ask whether or not Euclid's axioms are valid in our space; we must ask *what* axioms are valid in the space in which we live.

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* After this admonition he presented his own version of a definition to be used as a basis for a proof of the fifth axiom. It turned out that this definition was a tautology!

† The curvature of a sphere of radius r is by definition $K = 1/r^2\ (> 0)$. Every saddle-like surface has a negative curvature—i.e., $K < 0$. If $K = \text{const.}$, then such a saddle-like surface is called a surface of constant negative curvature.

‡ There are many other realizations of non-Euclidean geometry—e.g., Klein, Cayley, Poincaré, etc.

This situation makes our problem much more difficult because it leaves us no indication of how to proceed. We know on the basis of our past experience that there is one way we must *not* choose—the way paved with geometrical considerations only. Fruitful as this way may be for discovering new spaces with strange structures, it has no physical connection with the structure of the space in which we are living.

In the next section I shall describe one of the possible approaches; it is an approach characterized by a geometrical description of the physical world.

Relativity

We first have to clarify two notions which seem rather mysterious to the layman—namely, the notion of a four-dimensional space and the notion of a (gravitational) field.

To the mathematician, an n-dimensional space is by definition the set of all ordered n-tuples $(x_1, x_2, \ldots, x_n)$ of numbers. The numbers $x_1, x_2, \ldots, x_n$ are coordinates of the elements (called sometimes points) which constitute the space and which are assumed to be the primary a priori given elements. Thus, for instance, our space may be regarded as three-dimensional if we assume that the primary elements are points; it is in fact the set of all ordered triples (x_1, x_2, x_3). This space could be called a "point-space." If, however, in this same space we consider a straight line as the primary element, then the space is four-dimensional; it becomes the set of all quadruples (x_1, x_2, x_3, x_4) where $x_1, \ldots, x_4$ are coordinates of a line (line-space). Hence we live in a three-dimensional point-space which at the same time is a four-dimensional line-space. Moreover, this four-dimensional line-space is not flat but curved; *we are not capable of visualizing its fourth dimension, and furthermore it is impossible for us to detect its curvature!*

The space of Newtonian mechanics is a three-dimensional point-space independent of time. The space of general relativity is a four-dimensional space-time for which the fourth dimension is equivalent to the first three (spatial) dimensions (as it is the case for line-space). The primary element of this space is often called "event." We have to bear in mind that it is impossible for us to visualize this space-time even though we are capable of describing it perfectly well in terms of mathematical formulas.

In order to describe a (gravitational) field, a basic notion of general relativity, we shall use the following analogy: Assume that you are observing the surface of a river on a quiet night so dark that the surface of the river is indistinguishable from its surroundings. Assume that on the surface there is floating freely a lighted bulb. Since the night is quiet, the bulb will describe a straight line and that is all you see. If you are not in a poetic mood, you will at once remember the Newtonian law of inertia. If so, you will conclude that the bulb (the particle) moves freely without external forces. Assume now that a fish is approaching the bulb from beneath. It distorts the surface of the river, makes it wavy, and warps it. In other words, the surface is no longer flat—it is curved. The bulb does not move any longer in a straight line, although its path is still the shortest line between any two of its points. You do not see the fish but only that the path of the particle deviates from a straight line. Remembering Newton's second law, you will conclude that there is a force acting on the bulb, curving its path. The explanation of the phenomenon, however, is that the fish created a disturbance which curved the path of the particle. In other words, the fish created a field which curves its environment so that the path of the particle, even though still the shortest line (between any two arbitrary points), is no longer a straight line.

Replace the fish by our sun and the particle by a planet, and you have the situation we are aiming at. According to Newton, the orbit of a planet is not a straight line in our three-dimensional point-space because (among other things) the sun is "attracting" the planet. According to general relativity, the orbit is not a straight line because the mass of the sun warps the four-dimensional space-time so that the shortest line—i.e., the orbit—is no longer a straight line. You see that general relativity replaces the gravitational force vector by the new notion of gravitational field.

So far this is only attractive science fiction. In order to transform it into a scientific hypothesis, we must be able to describe the gravitational field and the resulting curvature of space by exact mathematical expressions. As far as the mathematical identification of the gravitational field is concerned, we shall use again an analogy. If one knows the metric of a sphere—i.e., the formula for the distance between any two of its points—one can easily find its radius r and its curvature $1/r^2$. The same holds for a four-dimensional space. Here the metric is defined by ten functions while the curvature of this space is defined by ten differential expressions of these metric functions. With a stroke of genius Einstein simply identified the gravitational field with the ten metric functions (which he called gravitational potentials) and was therefore able to find the curvature of the space in terms of the above ten differential expressions of the gravitational potentials. He found thus the curvature of the space-time expressed by means of the still unknown gravitational potentials. To find these ten unknown gravitational potentials we need ten equations. We know that all possible physical data relevant to this theory may be condensed into ten functions describing the physical state. With another stroke of genius Einstein equated the ten differential expressions for the curvature with the ten functions describing the physical data. In this way he obtained ten differential equations (field equations) for the ten unknown gravitational potentials. Solving these equations, we obtain the gravitational field in terms of the physical data. Thus was completed the hypothesis of general relativity. A hypothesis becomes a theory if, submitted to tests, it explains all observations and does not lead to contradiction. General relativity was tested and was found, in the first approximation, to yield the

results of Newtonian mechanics, while further approximations explained observations which eluded explanation by means of Newtonian mechanics. Thus the hypothesis of general relativity became a theory and is regarded at the present time as very near the true description of the physical universe.* The question is: What does this theory contribute to the problem of the structure of our space?

Conclusion

The answer to this question is rather unexpected. According to general relativity, we live in a four-dimensional curved space-time. We cannot, however, visualize a four-dimensional curved space, let alone its fourth time-coordinate, as being equivalent to the spatial coordinates. *Hence, according to this theory, we are living in a space whose structure we can never grasp or understand.* Disappointing as this answer may be, it still offers some consolation. It shows clearly that the puzzling questions concerning infinite or finite space, as well as questions about eternity, have no sense. We understand only the three-dimensional cross section of the four-dimensional curved space-time of the universe, and therefore the above-mentioned questions are a fortiori senseless.

Let me finish with the answer to a very reasonable objection which you would probably like to raise: What is the importance (if any) of the description of the universe that we can achieve by mathematical formulas without understanding intuitively their true interpretation?

Imagine a mathematician who was born blind. As a mathematician, he can create and master completely the theory of colors (because this theory is fully described by mathematics). However, he will never be able to interpret the true significance of his formulas. Moreover, if somebody tries to acquaint him with colors, telling him that fire is red and snow is white, he will erroneously connect red with the sensation of heat and white with the sensation of cold. Comparing this erroneous interpretation with his formulas, he will probably find contradictions. Being a mathematician, however, he will believe in his theory, despite these contradictions. He will realize that he will never be able to find the true interpretation of his theory, which he completely masters by means of mathematics. All that remains to him is the faith that there is some more powerful intelligence than his which understands not only his abstract theory but also its true interpretation.

In a manner similar to the plight of the blind mathematician above, it is beyond the capacity of our human brain to interpret the answers we found to the questions concerning the mystery of the structure of the universe.

* For the sake of completeness, we mention that Einstein proposed a generalization of this theory during his last years. This new generalized theory not only yielded the same results as did general relativity, but it opened the way for many new possibilities of interpretation of the universe. (See V. Hlavatý, *Geometry of Einstein's Unified Field Theory;* P. Noordhoff, Groningen, Holland, 1958.)

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A consideration of the environment of space, per se; the movement to, through, and back from this environment; and the time factor involved in space operations reveals the interscience ramifications of space medicine.

Interrelations of Space Medicine With Other Fields of Science

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THE INTERRELATIONS of Space Medicine with other fields of science may be best understood by starting with a brief consideration of its parent discipline, Aviation Medicine, or even with a brief review of the historical development of medicine in general.

At the dawn of human history, or at the time of the cavemen, medicine was essentially a primitive art of healing interwoven with mythology and astrology. With growing knowledge in the anatomy and physiology of the human body and in the natural sciences, this mystical kind of "medicine" had to give way to a rational, scientific line of thinking, which eventually led to the develpment of various branches and specialties. First, a differentiation of the original general medicine into surgery and conservative internal medicine became evident. The invention of the microscope and the development of new physical and chemical methods quickly broadened the knowledge of the human body. A multitude of subdivisions of medicine with respect to different anatomical organs and functional systems was the result. With the development of modern technology, transport, and travel, a specialization could be observed with regard to a specific occupation and environment such as industrial medicine and tropical medicine. One of the most important medical branches in the category of environmental medicine is *aviation medicine* which started some 40 years ago and has definitely aided the engineer and the flyer in the conquest of the air ocean, or aeronautics, according to its motto *volanti subvenimus*.

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And now, with the rocket at our disposal, astronautics, or the conquest of space, is in sight. In fact, we have already penetrated deeply into space immediately around us with unmanned research vehicles. And we have had manned flight operations of the space equivalent variety for the past several years. Manned space operations of the satellite type, lunar operations, and interplanetary and planetary operations are the logical further developments. All of these missions which will carry man completely out of the atmospheric environment so vital to him will pose medical problems unheard of in human history. That new medical field which studies the human factors involved and pertinent protective measures required in the penetration of space is space-flight medicine or, briefly, *space medicine*—a branch or an extension of aviation medicine. It is the mission of space medicine to contribute to the development, safety, and efficiency of manned space flight or astronautics. Space medicine can, therefore, also be called bioastronautics following a motto *astronautico subvenimus*.

The relations of space medicine, or bioastronautics, to other fields of science can easily be concluded from the definition of astronautics—the art and science of the design, production, and operation of spacecraft. The space doctor, therefore, consults with the engineer in preliminary design studies; he is able to give advice in the construction or engineering phase and will be largely responsible for the selection, indoctrination, and care of the crew in actual space operations and during return. These space operations include, primarily, manned operations, but some medical problems are involved in unmanned missile operations too. Thus, space medicine is more or less associated with all conceivable developmental lines of the rocket (from the simple one-

stage protorocket to the hypersonic ballistic vehicle flying in the space equivalence zones of the atmosphere), biosatellites, and finally, the space ship as the final descendant on the geneological family tree of rocketry.

I shall confine my discussion to three characteristics or elements of space operations:

(1) Space as an environment per se.
(2) The process of movement to, through, and return from this environment.
(3) The time factor involved in space operations.

These factors clearly reveal the ramifications of space medicine with other fields of science and offer us a complete panorama of the medical problems involved in space operation.

First, let's take a look at the environment per se. With regard to the physics of the upper atmosphere and near space, space medicine depends on exploratory tasks carried out in high-altitude balloons, sounding rockets and rockoons. This brings space medicine into immediate contact with geophysics and astrophysics, and with the research program of the Geophysical Year.

We know that the particle density in the area from the sun to the nearest star, Alpha Centauri, is about one particle per 1 cm.^{3}. This is almost a perfect vacuum. To simulate such a condition of emptiness, space medicine must resort to the field of vacuum technique. The best vacuum obtainable on earth is in the order of 10^{-8} mm. Hg. By convention the technical vacuum begins with 1 mm. Hg down. But physiologically the vacuum begins with about 47 mm. Hg which is the "boiling point" of water at the body's temperature of 37°C. This pressure corresponds to an altitude of 19 km. (63,000 ft.). This fact is the first impressive indication of what is in store in space from the standpoint of human physiology and biophysics. The atmosphereless environment of space requires, of course, the creation of an artificial or simulated atmosphere in a completely closed or *sealed cabin* for the crew. The development of such a cabin based on experimental studies in space cabin simulators brings space medicine in contact with the aircraft and high-altitude chamber industry, the air-conditioning industry, and submarine physiology. But the inside-the-cabin story in such a closed ecological system is only part of the real situation. Some of the problems will result from factors from the outside environment, such as the thermal, visible, and ultraviolet portion of solar radiation, cosmic ray particles, and meteorites. Here again, close cooperation with astrophysics, physiological optics, radiobiology, and meteoritics is a vital necessity. Experiments with artificial meteorites (experimental meteoritics) and their impact upon cabins may provide some clues for the protection of the crew. This is only a rough outline of the space medical relations which suggest themselves when we consider merely the space milieu as such.

The picture broadens when we take into account the process of movement to, through, and return from this environment. First, to get into space, powerful propellants of the chemical and/or of the nuclear type are required. This poses questions concerning toxicity of fuels and radiation hazards. Since the fuel must be spent in the first few minutes after take-off to throw a vehicle into the higher levels of, or even outside, the so-called gravitational crater of the earth, high accelerations occur during this time. Furthermore, decelerations are encountered during atmospheric re-entry. The study of their medical implications and of protection is a subject matter of *biodynamics*. In this respect we can also resort to the rich experiences that have been gained in experiments on large human centrifuges and on sleds. The hypersonic speed of a space vehicle through the atmosphere on both ends of the trajectory involves thermodynamics and thermochemodynamics.

Short flights of rocket-powered craft confined to the aerodynamically effective altitude range of the atmosphere follow, to some extent, the laws of *ballistics*. But above the mechanical border of the atmosphere which lies at about 120 to 140 miles, we enter the region of the *Kepler regime*, the arena of the artificial satellites. Now we deal with the laws of planetary motions or celestial mechanics. Actually, in contrast to theoretical celestial mechanics developed in astronomy, it is now experimental celestial mechanics with which we deal in astronautics and bioastronautics. The medical problem par excellence involved in Keplerian trajectories is that of tolerability of weightlessness. For short periods of time we study this question in ballistic or parabolic trajectories in jet planes within the atmosphere. We make comparative studies in swimming pools. But weightlessness in its true sense and over longer periods of time occurs only in flight operations above the mechanical borders of the atmosphere. Here we enter the world of *permanent weightlessness*. The study of this phenomenon involves both physiology and psychology. Since the function of the gravireceptors of the human body is eliminated in the nongravitational state, and the photoreceptors, or the eyes, are the only sense organs on which orientation in space depends, physiological and psychological optics may have something to say in the design of the cabin's instrumentation for navigation.

Flight operations outside the atmosphere deal exclusively with the gravitational fields of the various celestial bodies. Their effects are governed by Isaac Newton's law of gravitation. The atmosphere, as a navigational medium, is replaced by the spheres of predominant gravitational influences or gravispheres of the celestial bodies. Eventually, the escape velocity will push a vehicle beyond the gravitational control zone of the earth and this will lift space operations from the level of satellite operations or geocentric orbital flights to escape operations into the gravispheres or gravitational territories of other celestial bodies.

With this development, the time element obtains greater importance. Time and space flight is often associated with Einstein's theory of relativity concerning time dilation and aging at near light speed. But we find many important time problems in more realistic space situations within the confines of our planetary

system. First, in all kinds of true space operations there is no natural day and night. An artificial day-night cycle of a physiologically acceptable pattern, therefore, must be provided for the crew to keep it healthy and efficient. Thus, the science of biological rhythms enters the area of space medicine. Space operations of longer durations pose problems from the standpoint of logistics concerning food supply and the chemicals required for the regeneration of the cabin's air. Flight durations exceeding several months will require biological gas exchangers based on natural or artificial photosynthesis, so plant physiology and photochemistry will play a role in bioastronautics. And last but not least, the confinement and isolation in the crew compartment of the space vehicle, separated from the earth for a longer period of time, will pose interesting problems for the space psychologist.

In this respect, communication with the earth through the radio window of the ionosphere will be an important psychological factor. At this point I would like to add that telemetering of physiological data in animal experiments in ballistic and orbiting rockets is a new feature in physiological methodology.

So far we have enumerated interscience relations of space medicine resulting from the medical, physiological, and psychological problems as they can be expected during the active, passive, and atmospheric reentry phase of space flight.

Now, it is not the sole purpose of space operations to roam around the void of interplanetary space; rather, it is the final goal of astronautics to approach and contact other celestial bodies such as the moon, Mars, and, perhaps, Venus. This brings space medicine to a scientific line which we might call planetary ecology. In this, there are two aspects involved:

(1) What kind of environment would an astronaut find, for instance, on Mars with regard to himself; and what protective measures would he have to take to insure his survival? This involves human physiology, and, since the air pressure on the surface of this planet is about 70 to 80 mm. Hg corresponding to an altitude of 55,000 ft. in our atmosphere, it would specifically involve high altitude physiology, the development of oxygen equipment with pressure breathing, and/or pressure suits.

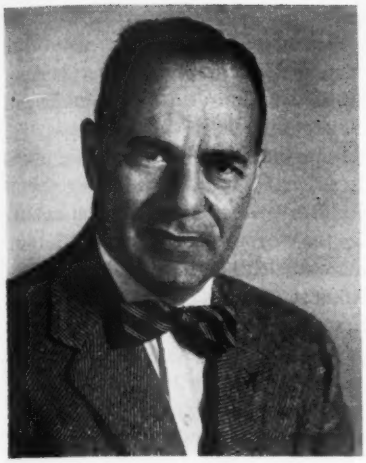
(2) The second question of interest to an astronaut and also of general human interest is that of the existence of indigenous life on other celestial bodies. This specific field of planetary ecology is also called *astrobiology*. Physical ecology studies an environment as to its suitability for the existence of life. Such a study includes all the various ecological factors such as temperature; light; the occurrence of liquid water; and the presence of oxygen, carbon dioxide, and other life-supporting chemicals. The ecological law of the minimum and maximum as the limiting cardinal points must be the guiding principle in these considerations. Its application is decisive for the question whether or not life is conceivable in any physical environment. This leads to a zonal aspect of the ecological conditions in the solar system and, as a result, to the assumption of a general life zone, or ecosphere, consisting of various belts such as biotemperature belt, biophotic belt, liquid water belt, and an oxygen belt concerning the physics and chemistry of planetary atmospheres. The oxygen belt includes Venus, Earth, and Mars. The outer planets form a hydrogen belt. The existence of these two photochemical belts can be understood only on the basis of a study of the historical evolution of the earth's proto-atmosphere, some $2^1/_2$ billion years ago, to the present day atmosphere or neoatmosphere in which we live.

This zonal ecological aspect is not only of interest concerning the celestial bodies but also with regard to the space between them, namely, interplanetary space. For instance, a space vehicle in the region of Venus encounters radiation conditions very different from those found at the orbital distances of Jupiter and, therefore, requires different measures for temperature control of the environment inside the cabin. This subject matter is part of a kind of ecological geography of interplanetary space or, more to the point, an ecological spatiography.

Returning to the planets in astrobiological studies we must not only consider the physical environment alone, but we must also take into account the possible reactions and the capabilities of living matter to adapt itself to a certain environment. This line of thought is called physiological ecology. Such studies lead to the vast field of physiological adaptations in the animal and, especially, the plant kingdom for comparison. With regard to the specific climate on Mars with its lack of oxygen, scarcity of water, and very severe day-night temperature variations, we must consider specific structures of the plants, if there are any, for storing photosynthetically produced oxygen such as intercellular air spaces as they are found especially in our aquatic plants, storing of carbon dioxide, storing of water as in our desert plants, strong absorbing power of the plant surfaces for infrared rays for temperature control, hibernation, and so on. All this calls for a closer respective examination of our terrestrial plants. American, French, and Russian astronomers have made comparative spectrographic studies on the green areas on Mars and terrestrial plants concerning the absorption bands of chlorophyll. If the astronomers were in the position to avoid the blurring effects of the earth's atmosphere and the telluric lines in their spectrographic studies, major progress in these studies would be realized. Space medicine has developed sealed gondolas attached to high-altitude balloons for such transatmospheric observatories. In this way astrobiology becomes a meeting place of astrophysics, spectrography, botany, and space medicine. Recently studies have been carried out on the survival of terrestrial microorganisms like bacteria in simulated Mars atmospheres. This experimental astrobiology combines planetology and microbiology.

Actually, astrobiology leads us to the very fundamentals of life itself as we know it, based on carbon as

(*Continued on page 37*)



SURVIVAL AT HIGH ALTITUDES

A discussion of the problem areas—pressure change, temperature variations, and high speeds—and their interrelationships existing in high altitudes.

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SURVIVAL AT ALTITUDE became a problem some 50 odd years ago when Wilbur and Orville Wright gave us the flying machine. Balloonists before then had established certain basic problem areas of human frailties and limitations, but the airplane intensified these problems. For example, today we are flying higher, faster, and farther than ever before. Today we have the equivalent of 35,000 to 45,000 hp. in our aircraft engines as compared with 3,000 hp. which was the best our piston-type engine of World War II could develop. Today we can travel nonstop around the world in 45 hours and 19 min. Today we exceed Mach 2, tomorrow Mach X. Today we must plan for tomorrow. What will be some of the limiting factors against which we must contend in our efforts to progress? Depending upon point of view, the answers will be many and varied. High on the list will undoubtedly be such items as fuels, materials, structural stresses, power plant, etc. However, the one constant limiting factor will be man himself. Since it is totally alien to our way of life to consider man expendable our progress will be determined by how well we can provide for his well-being even while we research the unknown. Therefore, we must examine this man not only critically but also sympathetically as an integral part of this vastly complex machine—the airplane.

What does a closer look at the individual—the pilot, the crew member, or the passenger—reveal? He is capable of adjustment to his terrestrial environment. He is constantly making adjustments for changes in external temperatures, for varying amounts of physical activity, for motion in space, for postural changes in relation to gravity, and for changing energy requirements. In aviation, however, the demands upon the compensatory mechanisms of the body are numerous and of considerable magnitude. Often the demands made upon the system far exceed the capability to meet the situation. We cannot progress far nor can we carry on for long if we disregard or minimize the position of man in this problem. Certainly we must at least provide man with basic protection against the hostile forces and environment to which he will be exposed. These environmental changes of greatest physiological significance in flight are:

(1) Changes in barometric pressure—with the related problems of hypoxia, dysbarisms (decompression sickness), respiratory and circulatory problems, and the inherent problem of cabin (atmosphere) pressurization.

(2) Variations in temperature.

(3) Movement at high speeds in three dimensions.

It is not the intent of this paper to present a detailed discussion of all factors of these problem areas, but an attempt will be made to show some of the interrelationships.

If we compare the atmosphere with an ocean of air at least 100 miles deep, we have done little more than hop around on the bottom. The maximum commercial flights and combat operations of World War II were at altitudes of 20,000 to 25,000 ft.—roughly only 5 miles above the earth. Today's aircraft, both military as well as commercial, have not progressed much further. (Even the advances in rocketry and space vehicles have done little more than take one more hop.) As recently as the early 1950's, flight activity was, for the most part, confined to the troposphere. The stratosphere was the frontier penetrated by dedicated men in the most advanced aircraft, and the ionosphere was left to shooting stars and rockets. Today, you know that these low altitudes of the troposphere are a thing of the past, but one must crawl before he can walk and run. However, it is in these low-altitude flights, up to 40,000 to 45,000 ft., that we encounter the many problems of human life.

What does an examination of this ocean of atmosphere reveal? The decrease in atmospheric pressure is very rapid, so much so that by the time one has passed through the 34,000-ft. level, three-fourths of the total

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air mass, and approximately 90–95 per cent of all water vapor content, has been left below. The temperature decreases at a relatively constant rate of 2°C./1,000 ft., until a temperature of approximately −55°C. is reached. Practically all weather occurs in the troposphere. There are turbulence, icing, and winds which reach velocities as high as 200 miles/hour. You know them as jet streams. The stratosphere, on the other hand, is characterized by having a temperature of at least −55°C., little or no water vapor, no turbulence, possibly some horizontal winds, but no major vertical disturbances. What then, are some of the problems arising from these conditions?

Of prime importance is the decreasing partial pressure of oxygen with decreasing atmospheric pressure. At ambient pressures up to 10,000 ft., man can perform reasonably effectively if he does not stay at the higher level of 10,000 ft. for more than 4 or 5 hours while breathing the ambient air. Above this level it is imperative that pilots, crew members, and passengers inhale supplemental oxygen in order to maintain efficiency and to prevent performance deterioration. The condition known as "hypoxia" will result when the partial pressure of oxygen drops below 2 psi. The physical and mental capacity of an individual is controlled by the partial pressure of the available oxygen. The onset of hypoxia is insidious. There is no warning. There is no pain. There is a gradual decrease in mental agility, and effective physical activity resulting in fatigue, drowsiness, and sluggishness. Coordination is lost. Visual acuity is decreased. The individual loses his most precious asset—the ability to analyze and self-evaluate critically. Clear judgment is not possible. An extended period at altitude will increase the severity of these conditions and produce other more serious and disastrous consequences: nausea, headache, collapse, coma, and, ultimately, death.

As in all things, there is individual variation in the amount and extent of disability accompanying a given degree of hypoxia. However, the data of Table 1, a result of years of observation of normal, young, healthy men of the USAF, will serve to emphasize the dangers to anyone exposed to hypoxia.

TABLE 1

Altitude (thousands of ft.)	Behavior Characteristics
0– 5	Normal behavior, fatigue on long exposure
5– 8	Undetectable behavior change on short exposure (30 min.); headache, fatigue if prolonged exposure
8–11	Detectable behavior changes on exposures exceeding 1 hour
11–20	Considerable handicap in 15 min. (especially above 16,000) preceded by such symptoms as sleepiness, headache, dizziness, impaired vision, personality changes, impaired judgment, loss of muscular coordination, increased pulse and respiratory rate, and cyanosis
20–25	All of the above in more serious and acute fashion with serious handicap within 3–10 min.
25–30	Individual in danger of imminent collapse in 3 min. (or less)
30–40	Individual in danger of imminent collapse in 1 min. (or less)

This data applies to the resting individual. Add other stress factors such as exercise (work), postural requirements, carbon monoxide and carbon dioxide concentrations, alcohol, excessive use of tobacco, and heat and cold, and the dangers have been compounded.

In view of these data, commercial airlines have pressurized their aircraft so that an artificial environment not to exceed 8,000 ft. can be maintained in the cabin. This is referred to as the "cabin altitude" as differentiated from the "ambient altitude," which may be as high as 36,000 to 40,000 ft. Combat aircraft use similar systems, but maintain different cabin pressure relationships. In military aircraft, the use of oxygen masks and systems is necessary in addition to pressurization, since at altitudes over 10,000 ft. supplemental oxygen is an absolute requirement. While pressurization, and in the case of military aircraft, oxygen systems, minimize the dangers of hypoxia, there is introduced the very real danger and hazard of the sudden loss of pressure from the cabin. It is possible to ascend to altitudes where, even with supplemental oxygen, survival is not possible unless the delivery of the oxygen is under a positive pressure, and even then it must be pointed out that the human can tolerate only so much positive pressure without counterpressure. These, of course, are military and not civilian problems, but if we are to conquer space, these problems must be met and resolved. To this end, both the USAF and the U.S. Navy are working on pressure-suit equipment.

Cabin pressurization helps to overcome another real and vexing problem, decompression sicknesses. Without pressurization the human body will react according to the laws of physics with which we are all familiar: Boyle's law for expanding trapped gases, Henry's law for solubility of gases; Dalton's law of partial pressures and resultant oxygen deficiency. When one considers that the body gases are wet gases, the problems are even greater. Aeroembolism, commonly referred to as "bends," is similar to the well-known condition of caisson disease. The nitrogen, dissolved in tissues and blood stream under atmospheric pressure, comes out of solution with pressure decrease, according to Henry's Law, and these bubble formations, as long as they form outside the circulating blood, will result primarily in considerable pain. This pain may be so severe as to produce collapse. Usually there are multiple collections of gas, generally at the moving joints such as knees, elbows, fingers, and sometimes in deep muscle tissue. Hence there are several areas of pain, and it is most urgent that the individual descend to lower altitude and higher pressures to force the nitrogen back into solution in body fluids. In general, the occurrence of this is at altitudes in excess of 30,000 ft. If the nitrogen bubbles form to any great extent within the circulatory system itself the condition is even more serious and will lead to central nervous system collapse. Descent to lower altitude is an absolute requirement if life is to be sustained.

A condition referred to as "chokes" results from the same mechanism of nitrogen bubble formation but is

localized in the pulmonary mechanisms. The sensation of not being able to breathe, accompanied by a racking, hacking, unproductive cough with deep substernal burning pain, indicates chokes. Immediate descent and 100 per cent oxygen is indicated. However, as has been indicated, successful cabin pressurization minimizes these problems. But what happens if cabin pressurization fails? One of the important things involved in loss of cabin pressure is the rate at which pressurization will be lost. If it is lost slowly by a leak, instrumentation will usually indicate this, and proper procedures can be initiated—the most important of which is descent. If, on the other hand, the cabin pressurization is lost very suddenly—in seconds as might result from the loss of a window or door, or gunfire piercing the sealed compartment—the altitude at which this happens and the pressure differentials and air densities will be the critical features, for in a matter of seconds, the occupant or occupants, will literally be rocketed from the comparatively safe altitude of the cabin to the ambient altitude of the aircraft. Should this occur as low as 30,000 ft., the time of useful consciousness is measured in minutes, usually less than 2. Descent procedures must be initiated immediately. Supplemental oxygen must be immediately available. The intense cold of high altitudes (−55°C., −67°F. at 35,000 ft.) will prevail. The physics of gas laws will become operative.

Consider for a moment transport in high-altitude aircraft. The problems inherent in the situation are not for future considerations. They are upon us now. They must be solved now. The contemplated use of jet airliners for commercial air transportation should serve to emphasize the urgency of the need for adequate controls and procedures in dealing with the problems of reduced barometric pressures. The large number of passengers involved in a single commercial operation would further complicate a relatively simple military matter, for in the very factor of numbers is added the confusing pattern of varying ages, temperaments, states of health and well-being, and abilities to react to emergencies inherent in so heterogeneous a group.

Consideration of passenger requirements for emergencies in commercial jet aircraft usually brings to mind the British experience with the Jet Comets. The Comet disasters point up one type of accident which will result in major damage. Any attempt to reduce the outcome of such a disaster once it has occurred will be ineffectual. All engineering efforts and accomplishments must be directed to the prevention of such disasters. Even the minor damage incident such as a cabin leak or a window failure will produce serious consequences to the well-being of the passengers and crews of airliners when traveling at altitudes above 25,000 ft. unless proper precautionary measures can be or have been taken.

Human physiological limitations to high-altitude flight have been indicated by Table 1. The obvious solution is to maintain a cabin altitude of not more than 8,000 ft. if passenger safety and comfort are to be provided. However, it must also be obvious that the increased pressure differentials increase the possibilities for decompression and the greater the differential of pressures the more severe the consequences on the passengers and crew. Immediately after the decompression emergency oxygen must be provided for the passengers and steps to initiate descent must be taken by the crew. If supplemental oxygen is not immediately available to passengers and crew after a rapid decompression, hypoxia will prevail in a very short period of time.

Referring again to Table 1 it becomes apparent that an exposure of from 5 to 10 min. to an ambient altitude of 15,000 ft. will result in a very serious handicap to most individuals. Since one of the side effects of hypoxia is to produce a false state of well-being, an "all's right with the world" attitude, the individual suffers a double jeopardy—(1) hypoxia and (2) an inability to recognize it for what it is. Coincident with a condition of hypoxia is the available time of useful consciousness. By this is meant that time during which the individual would be capable of performing those things necessary for self-preservation. With respect to time of useful consciousness there isn't much variation from individual to individual so that the following represents a generalized picture of human capabilities when one is suddenly exposed to ambient altitudes above 20,000 ft.:

Altitude (Ft.)	Time of Useful Consciousness*
22,000	7–10 min.
25,000	3–5 min.
30,000	1 min. or less
35,000	20 sec.
above 35,000	9–12 sec.

There are other problems involved in high-altitude flight besides hypoxia. One of these is "bends" and its seriousness has been indicated. The possibilities of bends incidence in a group of passengers who have been breathing cabin air at 4,000 ft. to 8,000 ft. and suddenly find themselves at 35,000 ft. or even higher is extremely great. Experience with military has shown that without proper denitrogenation bends will occur within 10–12 min. for 30 per cent of the population when exposed to altitudes of 30,000 ft. to 40,000 ft. and could reach 50 per cent in 15–20 min. In an unselected population the onset of bends might conceivably be more rapid and more severe. These facts will certainly have a great bearing upon how high flight might be continued in the unpressurized state.

Rapid or explosive decompression of airliner pressurized cabins will require immediate emergency procedures if the decompression occurs above 20,000 ft. One of the incapacitating factors after a decompression could be the effects of expanding gases in the gastro-intestinal tract. This could become very painful and, depending upon the time at altitude and the altitude itself, will become a problem with a variable percentage of the population. Human tolerance to gas expansion

* This is true for the resting passenger. Work, activity, anxiety, apprehension will cut these times in half.

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in tissue structure is roughly 2.5 times normal. It might be pointed out that the difference in pressures from 8,000 ft. (10.91 psi) to 40,000 ft. (2.72) would result in a relative gas expansion 5.5 times the original.

Referring again to the temperature conditions prevailing at high altitudes, we are faced with yet another problem area. Regardless of the temperature variations on the earth's surface, whatever the sweltering temperatures are at sea level, it is always intensely cold above 35,000–40,000 ft., even above the equator. Every flight into the stratosphere will mean that temperatures of at least −55°C. (−67°F.) will prevail. These extremely cold temperatures require additional protection in the form of heated cabins for all personnel flying in the aircraft. At these temperatures frostbite will occur in only a few minutes.

The question of human tolerance to temperature extremes under varying degrees of humidity remains one of the great problems confronting the aviation physiologist. Recovery from wounds suffered by gunfire is often more easily achieved than recovery from damage incurred as a result of frostbite.

Speed of itself produces no objective or subjective effects so long as the velocity and direction remain constant. With the earth rotating once in 24 hours, each of us is traveling at a speed of approximately 1,000 miles an hour while we move about on the surface of the earth. A passenger traveling in an airplane in straight and level flight is not conscious of the sensation "speed."

The human problems arise in getting the airplane up to a constant speed (acceleration), and in slowing it down (deceleration). Each of us is familiar with the sensation produced by stepping on the accelerator of an automobile. The same is true in launching an airplane by catapult. It is possible to tolerate terrific speed if the increase in speed is gradual and the force applied over a considerable time. The sudden deceleration produced by crash landing is the crucial problem in linear deceleration. Thus the problem of deceleration is initially one of providing a smooth constant deceleration over as long a period of time and at as great a distance as possible. In addition to the gravitational forces existing during acceleration and deceleration, the force of gravity acts on the human body when a change of direction is made. It was early determined that the maximum human tolerance to this gravitational force was between 4*g* and 7*g* for periods over 4–5 sec. In other words, the weight of the blood in the body would increase along with the other body elements so that the heart would not be capable of forcing blood up into the head. The net result is, first, a loss of vision, called blackout; secondly, if continued long enough, the loss of consciousness itself. It became apparent that in order for airplanes to travel at high speeds and yet be maneuverable, the pilot needed protection against the gravitational force produced by turns at high speeds. For the military pilot a "*g*-suit" was developed during World War II as a means of combating the gravitational forces. At the most, these suits were capable of increasing the *g* tolerance by 1–1½*g*. In any attempts to alleviate the effects of *g* forces, it must be remembered that human tolerance to these forces is a function of such factors as the magnitude of the acceleration, the duration of the exposure, the rate of change of the acceleration, the distribution of the force over the body, and, last but by no means least, the orientation of the body with respect to the imposed forces. It is also most important to bear in mind that the pilot's reaction time and/or ability to function is not characterized by a gradual deterioration due to progressive failure but rather is a representation of the inability of the total organism to compensate for the effects of the stress imposed on it. He is simply overwhelmed.

As flights of greater duration become possible, the problem of fatigue comes to the fore. The use of two or more pilots could be a way to answer this problem and simplify the pilot's job, but, in recent years, aircraft have been developed capable of sustained flights greater than 24 hours duration, and we must not forget in-flight refueling. Pilot efficiency must be at its best to make a successful landing, and hence, flights of long duration place a greater strain on the pilot than the same number of hours spent at intervals in the air. Not only the pilot, but the radar operators, navigators, and engineers face a similar problem. Extensive psychological research is going on to determine the periods of time during which a man can perform a given complex task with maximum efficiency. A concomitant problem is the investigation of control knobs, instrument displays, and all types of devices designed for use of aviators, with a critical evaluation of the "human engineering" requirements and, if necessary, a redesign of equipment so that it can be used with the greatest efficiency and the least fatigue.

This factor of fatigue cannot be overlooked or minimized. It is a potent weapon against the pilot and crew and shows up in many ways—physically, mentally, and psychologically. Unfortunately the pilot and crew usually are unaware of the signs at the time. For example, the fatigued pilot, while he may complete the necessary operations, requires greater than normal stimuli to establish the appropriate responses. There will probably be errors in his timing, some elements in a task sequence will probably be overlooked, accuracy and smoothness of performance will deteriorate. These are just a few of the skills which suffer from fatigue.

In this present age of high-speed jet aircraft a moment's hestitation or a human error is much more serious than in slower propeller-driven aircraft. Consider for a moment traveling in an aircraft at 1,800 m.p.h. Something suddenly appears ahead of the aircraft. It will actually take the pilot 0.4 sec. total time for central perception and action during which time he would have travelled 1,042 ft. If he had to recognize friend or foe it would take at least 0.8 sec. additional and he would have traveled another 1,952 ft. If two aircraft are on collision course when they break out of clouds, 1,800 m.p.h., 3,000 ft. apart, they would crash before anything could be done about it. If they were only 500 ft. apart they would collide without either pilot ever hav-

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ing seen the other. The fatigued, inattentive, preoccupied pilot writes his own ticket. Unfortunately many others are involved in the ultimate outcome of any lapses or shortcomings.

Probably everyone who has flown has experienced an attack of slight nausea and an uncomfortable feeling from the strange motions produced by rough air. Motion sickness has been the subject of a great deal of research. It can be separated into at least two separate and distinct entities. There are a group of people who have a predisposition to motion sickness. These individuals become carsick or trainsick, as well as airsick and seasick. Little, if anything, can be done for these people, but fortunately, they comprise only a small number of the population. The other form of motion sickness arises primarily from apprehension, and is commonly found in novice air travelers and student pilots. It disappears as experience and confidence increase and is to be regarded as a normal occurrence. In short, everyone is subject to motion sickness at times, but some people have it all the time.

An interesting physiological problem will arise in all flights above 12 miles, 63,000 ft., (sometimes referred to as the Armstrong line) since it is at approximately this altitude and at body temperature that gases come out of solution rapidly. (The popular but mistaken version is that blood "boils" at an altitude of 12 miles.) Of course, pressure cabins could be perfected to the point of increasing the effective atmospheric pressure within the cabin to some lower equivalent altitude, but, for emergencies, the individual must be given some additional protection. This protection is now available to the military pilot. On December 13, 1956, Major Arnold I. Beck made an ascent to an equivalent 198,770 ft. ambient in the High Altitude Research Chambers at Wright Air Development Center. Major David Simons made his balloon flight to 102,000 ft. with full protection in the event of gondola failure. Lewis and Ross of the U.S. Navy have made at least two flights above 75,000 ft. in a gondola carried aloft by balloon and Capt. Iven Kincheloe has flown in the Bell X-2 to 126,000 ft. Each was fully protected in the event of a cabin pressurization failure. It might be said that flight *in vacuo* is theoretically possible, although there are many practical considerations to overcome: fuels, propulsion, sustaining life, etc.

What does the future hold for us? One thing is certain. The future in aviation today is not as uncertain to us as it was to the Wright Brothers 50 years ago. The sky is the limit!

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Interrelations of Space Medicine *(Continued from page 32)*

the structure atom of living matter. And it stimulates speculations about the possibility of life based on other atoms than carbon. This extra carbonic biology offers a prolific substratum for science fiction, which may not be so fictitious after all. All this shows the great multitude of aspects and scientific interrelations in the field of planetary ecology or astrobiology.

Now, what is the use of all these studies? To answer this, I would like to refer to an example in the inanimate world. Helium was not discovered first on the earth. Rather, the existence of this element was postulated from a strange yellow line in the spectrogram of the chromosphere of the sun in 1868 and consequently was given a name derived from the Greek word for the sun, Helios. About 25 years later in 1894 helium was found on the earth also. In the same way, comparative spectrographic studies on the surfaces of Mars and on the inorganic and organic surface features on earth may furnish information to geology and botany which is not available as yet.

The same may be said of the study of the medical problems involved in space operations. Even if manned space flight were never to become a reality, studies of this kind with an extraterrestrial cosmic trend might be very valuable to us. The study of the cosmic rays has already contributed considerably to our knowledge in radiobiology. Eliminating gravity experimentally might increase our knowledge about the coordination of our statokinetic reflexes and of the movement and orientation of our bodies under normal gravitational conditions just the same as the elimination of the vitamins in food has brought about the knowledge of their function. In fact, we do not find in the physiological textbooks, monographs, and handbooks the words "zero gravity" or "weightlessness," and yet this condition is involved in the "fall reactions" of cats, etc., which are described at length in these publications. Apparently, it was overlooked until space medicine brought it to light.

So, it can be hoped that space medicine will make its contribution to medicine in general, and to the many border fields to which it is related, just the same as its parent discipline aviation medicine has done in various biomedical fields such as in the physiology of respiration, blood, and circulation. But manned space flight is on its way in its first phase; space equivalent flight, and manned satellite flight soon may be in full orbital swing. It is interesting to see that medicine which, at the time of the caveman, was in close association with astrology is now in the version of space medicine related to astronomy. This association with matters of extraterrestrial celestial nature is perhaps the most striking feature in the interrelations of space medicine with other fields of science.

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The Development of Satisfactory Spin Characteristics for the T-37

Harry R. Clements
The Cessna Aircraft Company

From the beginning, the T-37 was beset with spin problems because of type specification requirements and the design philosophies adopted to satisfy them.

FIG. 1. T-37A configuration.

THE T-37 is an airplane designed for primary phase training of Air Force pilots. It is the result of a competition conducted in 1952 which required handling qualities and spin characteristics according to military specifications. For spins these requirements for a primary trainer are briefly:

(1) One and one half turn recovery from 5 turn clean configuration erect spins, 1 and 2.5g entries. Loadings heavy each along the wings and fuselage are required, as well as the most aft c.g. loading.

(2) One turn recovery from a 1 turn landing configuration spin.

(3) One and one half turn recovery from a 2 turn clean inverted spin.

(4) Recovery from spins of case 1 with ailerons with and against the spin.

These were the objectives of the development program described, along with contributing factors, in this paper.

CHARACTERISTICS OF THE ORIGINAL CONFIGURATION

Physical Characteristics

The T-37 had a built-in spin problem. This problem was fostered by the type specification requirements for the airplane and supplemented by the design concepts adopted to satisfy those requirements. One of the contributing factors from this source was an unknown through a major part of the aircraft development, and will be discussed in detail later.

Updated and revised for exclusive publication by the *Review*, this article is based on a paper of the same title presented by the author at the WADC Spin Symposium, February 27–28, 1957.

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The type specification stated that the airplane should have: side-by-side seating, high performance (for a primary trainer), and low weight.

Cessna, guided by the apparent trend toward all-jet operation, chose small turbojet engines for their proposal. To obtain the desired performance and weight, the smallest possible airplane physical size was utilized. This placed limitations on the space available to store the relatively large amount of fuel necessary to accomplish its mission with jet engines. Because it was to be a primary trainer, simplicity of design and operation were keynote, and good visibility was given prime consideration.

These concepts defined two features that were to have great effect on the spin characteristics of the T-37: the fuselage shape and the fuel system.

With the fuselage width established by the seating arrangement and the depth by forward visibility requirements, the fuselage nose was of necessity shallow and flat. The tail cone contours were blended continuations of the forward ones with the tail length defined by static stability criteria.

The combination of fuel capacity requirements, space available, and desire to minimize center of gravity travel dictated that the wing be used to carry a major portion of the fuel. Since fuel management was felt to be an unnecessary complication, it was attempted to simulate a single fuel cell in the airplane by interconnecting all wing cells and a single fuselage tank which fed both engines. Initially this was strictly a gravity system,

with a filler at each wing tip. This was modified early in the program to include a proportioner to pump fuel from each wing at equal rates.

Spinning Characteristics

The disposition of the fuel in the wings led to high lateral mass loadings, since, at maximum capacity, the fuel accounts for one-third of the gross weight of the T-37. The value of the inertia yawing moment parameter, $(I_x - I_y)/mb^2$, for the airplane is positive for the greatest portion of its flying range. This puts it in the "transport loading" spin category which places emphasis on the elevator as a recovery control. Recoveries for this category usually occur abruptly after antispin control has been held for some time.

The spin and spin-recovery characteristics of the original prototype configuration were both unsatisfactory and inconsistent. It is doubtful if a steady spin was ever realized with this configuration, yet several uncontrollable conditions were reached. Flight-test data could hardly be analyzed to obtain accurate spin characteristics, although some trends were uncovered. The following, showing the salient spin features for the original XT-37 configuration, are flavored considerably with wind-tunnel test results.

turn rate—166° per second
angle of attack—68°
altitude loss—415 ft. per turn
turns for recovery—$4^1/_2$

Modifications to the Original Configuration

Extended Tail Arm

Minor modifications were made to the original configuration without appreciably improving its spin characteristics. It was apparent that a basic lack of damping and recovery power existed. To overcome these factors, a major improvement in tail design was employed. The empennage was extended 25 in. aft and the horizontal tail was raised 6 in. on the vertical tail. The horizontal tail size was reduced consistent with maintaining the former degree of longitudinal stability which was felt to be adequate. The vertical tail size, however, was increased to supplement the damping and recovery control expected from the extended tail arm.

With this modification consistent spin recoveries began to be obtained. They were of the variety to be expected with a high wing inertia loading. The spin parameters and recovery characteristics were still somewhat erratic, however, indicating that some factor contributing to the spin was not understood.

Increased Elevator Travels

Flight results confirmed that the elevator was the primary recovery control for the T-37. The number of turns for recovery, for the average, was still greater than was desired, and occasionally an excessive number was required. The elevator down travel was increased to counteract this occasional "poor" spin and was apparently of some help.

The balance of pitching moments in a steady spin requires a reduction in spin rate for an increase in nose-up moment at constant attitude.[1] A reduction of spin rate would, of course, be instrumental in reducing the turns for recovery. An increase in up elevator travel from 18° to 26.5° (physical limit of the existing system) resulted in a decrease in rotation rate of about 15 per cent with a corresponding reduction in turns out.

Other Minor Modifications

Several other minor modifications were attempted and the more successful ones were retained. A ventral fin, which provides damping at high rotation rates, was one of these. Another was the upswept "dihedral" wing tip. This was designed to provide a restoring moment to overcome wing tilt in the spin and was investigated because the occasional "poor" spins seemed to exhibit excessive inward sideslip. This was partly attributable to the relatively thick and highly cambered wing-tip airfoil sections (NACA 2412) selected for their good low-speed characteristics. They retain a good portion of life past stall and cause a yawing moment due to rolling which tends to rotate the airplane inner wing down.

Two common spin "fixes" which were unsuccessful on the T-37 were aft fuselage strakes and stabilizer fillets. They are both designed to improve fuselage (or fin) damping.

Nose Strakes

It is known that fuselage cross-section shape can have an important bearing on its damping contribution in spins.[1] In some extreme cases it can actually produce autorotative couples.[2] The fuselage of the T-37 is not favorable in this respect because of its flat shape and small projected side area.

Strakes placed on the aft portions of a fuselage have been used on other airplanes for some time. They add to the fuselage damping by retarding the flow around it and building up positive pressures on the prospin side. (The antispin side would be essentially separated.)

It was felt that more favorable results would be obtained with strakes on the nose because:

(1) They would be operating in a region of less disturbed flow (outside of the wing wake effects) and would have better opportunity of doing the intended job.

(2) They would produce nose-up pitching moments (being effectively low aspect ratio lifting surfaces at high angle of attack) which would tend to further slow rotation.

(3) There was a larger amount of effective damping area presented underneath them at the forward location.

See Fig. 1 showing plan form of strakes on the T-37A nose.

Static low-speed wind-tunnel results substantiate the trends expected from the strakes. Fig. 2 shows that

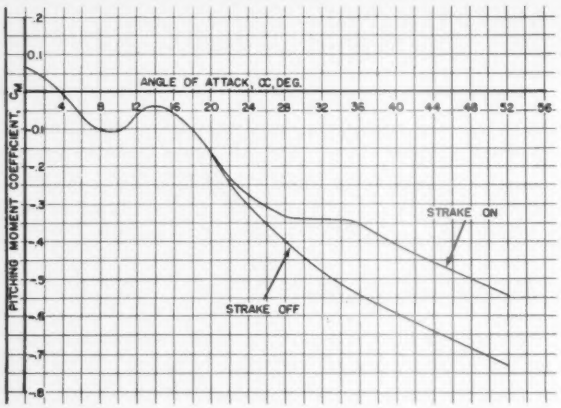

FIG. 2. Effect of nose strakes on pitching moment.

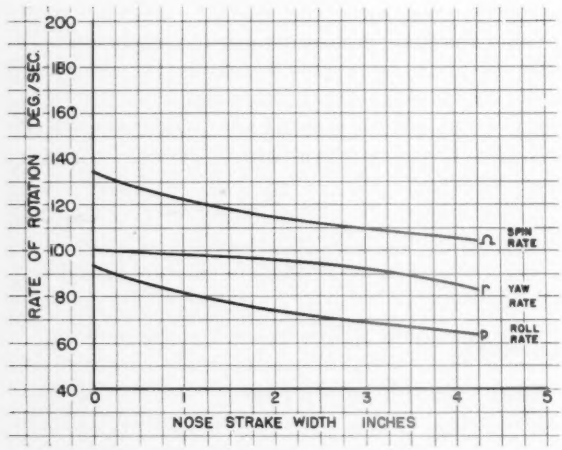

FIG. 3. Effect of nose strakes on rotation rates.

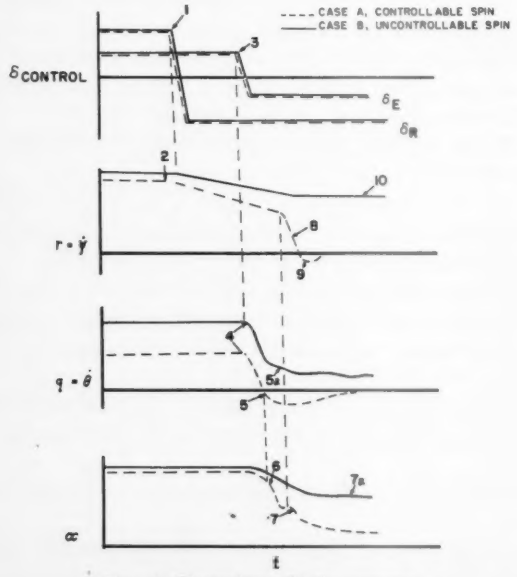

FIG. 4. Chronology of spin recovery.

they produced a substantial increment of nose-up pitching moment at high angles of attack. It was also found that they produce yawing moment in the direction opposite to the direction of sideslip. While this is destabilizing statically it would be reflected as an increase in damping for rotational motion.

Flight tests conducted with strakes of various widths showed that the reduction in rotational velocity obtained was proportional to the strake size (see Fig. 3). The reduction in number of turns out of the steady spin was a similar function of the strake size.

Large nose strakes had a tendency towards longitudinal instability near stalling speed, and undoubtedly caused losses in static direction stability as well as excessive drag. With the strake size chosen, 2 in. in width, no change in handling characteristics in the normal flight range occurred.

Fuel System

The modified configuration, prior to the addition of nose strakes, was not completely devoid of uncontrollable spins. Upon weighing the airplane immediately following one of them, it was found that a large degree of lateral mass asymmetry existed.

This was discovered to be caused by asymmetric placement of fuel in the wings during refueling. This was inherently possible if the aircraft were refueled when not laterally level, and could be augmented by refueling technique. Since the tip-most fuel tank was relatively small, time delays occurred while fuel ran out of it and into the other tanks. If the person refueling the airplane was not patient he might stop while one wing was yet capable of receiving considerably more fuel.

Lateral mass unbalance causes wing tilt in the spin because of an asymmetric weight and aerodynamic force situation. For a wing inertia loading this in turn causes:

(1) An increase in rotation rate in a spin in the heavy wing direction since the inertia yawing moments will be prospin. (Note that a reduction in spin rate occurs if spinning is done in the direction of the light wing.)

(2) The existence of pitching motion in the steady spin since part of the spin rotation rate is about the Y-axis. This will be nose-up for spins in the direction of the heavy wing and nose-down for opposite spins. As an extreme example, consider an airplane in a steep spin with 90° of wing tilt. The entire spin rate would be pitch rate.

For spin in the heavy wing direction the increased rotation rate is adverse from the standpoint of overall recovery capability, but the nose-up pitch rate imposes an especially severe requirement on the elevator when it is the primary recovery control. The pitch rate due to wing tilt is not such as to change angle of attack of the spin. The elevator must reduce this rate to zero, however, before a down pitching motion can occur which will reduce angle of attack below the stall value and allow recovery. This was found to be a primary difference in the time histories of the normal and uncon-

trollable spins, even when they occurred at similar rotation rates. Referring to Fig. 4, the sequence is as follows: (1) antispin rudder application, (2) yaw rate decrease, (3) recovery elevator application, (4) pitch rate decrease, (5) pitch rate becomes zero or (5a) pitch rate becomes a positive minimum value, (6) angle of attack decrease, (7) angle of attack becomes below stall value or (7a) angle of attack becomes a minimum value greater than stall angle, (8) further yaw rate decrease, and (9) recovery at zero rate or (10) no further yaw rate decrease, giving a new steady spin condition without recovery control available.

Flight-test results of a planned asymmetric fuel spin program demonstrated the expected variation in pitch and spin rates (see Fig. 5). The turns out of these steady spins with a standard recovery technique showed an increase with increasing unbalance also for spins in the heavy wing direction. No gain was made in the light wing direction, since apparently a given amount of time is necessary to dissipate the energy of steady spin.

This fuel asymmetry was evidently the unknown factor that had plagued the T-37 spin program from its inception. With the advent of close lateral fuel control consistency appeared in the test results and spin characteristics.

To combat this problem, the fuel filler was moved to the larger leading-edge tank, and the fuel level is at the spillover point when at full capacity. This did not completely alleviate the effect of refueling on an unlevel platform, but satisfactory spin specification compliance has been demonstrated with the most adverse condition thought possible because of this cause alone. As a precaution, individual wing fuel gages were added so that levels can be compared prior to spinning, and the airplane is placarded against intentional spinning with large amounts of unbalance.

Unintentional spinning is not likely in this airplane because of its gentle stall and the large (50 per cent) rudder deflections required to initiate autorotation. It has been demonstrated that with strakes, recovery can be accomplished with the greatest amount of lateral unbalance yet known to exist if full-down elevator is briskly applied and held.

Characteristics of the Final Configuration

Physical Characteristics Established by Spins

The spin problem on the T-37 established several of the physical characteristics of the aircraft. Summarizing, these are:

(1) Aft c.g. limit (established at the rear-most location tested in spins).
(2) Up- and down-elevator travels.
(3) Tail length and vertical tail size.
(4) Nose strakes and ventral fin.
(5) Dihedral wing tips.
(6) Fuel filler locations.

None of these are items of great expense, weight, drag, maintenance requirements, or deviations from standard production procedures. The heaviest of them, the tail length modification, caused a weight increase of 24 lbs. The strakes and ventral fin do give small increases in wetted area, and the leading-edge location for the fillers is also somewhat detrimental from a drag standpoint.

Some of these items, however, actually resulted in improvements in other characteristics. For instance, the revised tail length gave greater damping in the normal flying range, the dihedral tips improved lateral stability, and the relocated filler position resulted in a reduced refueling time.

Spinning Characteristics

The spinning characteristics of the final production configuration, which incorporates the above modifications, are exceptionally good despite the "transport-type" loading. They present a remarkable improvement over the original ones. The spin is steeper and slower, and turns out are greatly reduced.

The production T-37A configuration has satisfactorily complied with all Military Specification spin requirements for a primary trainer:

turn rate—118° per sec.
angle of attack—45°
altitude loss—500 ft. per turn (plus 2,000 ft. in recovery to level flight)
turns for recovery,—$1^1/_4$

Conclusion

Since this paper was originally presented, the T-37A has been subjected to more extensive spin flight investigations to provide comprehensive information for a variety of conditions and possible pilot techniques in entry, steady spin, and recovery. This was thought

(*Continued on page 57*)

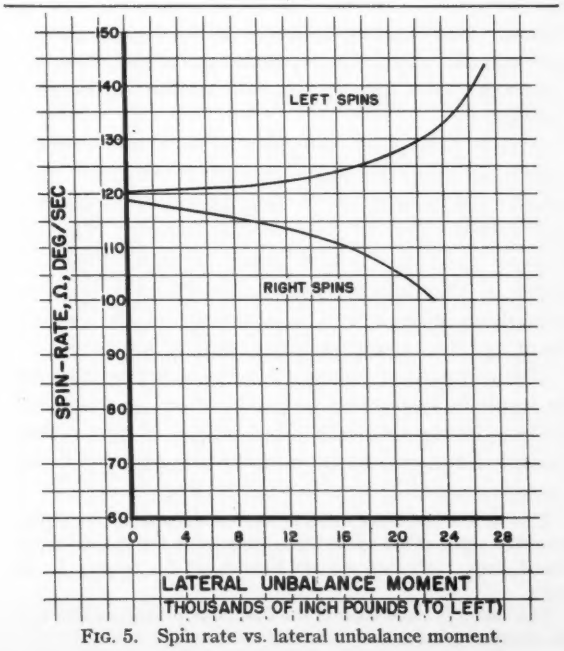

Fig. 5. Spin rate vs. lateral unbalance moment.

Propulsion Systems for Space Flight

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Typical designs for chemical, nuclear, and ion rocket engine systems are described, and available information on radiation, particles, and external (gravitational) force effects in outer space is reviewed in terms of effects on propulsion systems.

SYMBOLS

a	= missile acceleration
I_s	= specific impulse, sec. (lb. of thrust produced per lb. of propellant expelled per sec.)
m_o	= gross missile mass
m	= molecular weight
t	= time
ΔT	= overall power-plant temperature difference
T_c	= combustion temperature
v_p	= missile burnout velocity
v_{ex}	= propellant exhaust velocity
γ	= ratio of specific heats
P	= rocket engine power

THE RECENT successful launchings of satellites have indeed heralded the new era of space flight. Just how rapidly the development of satellites and space exploration systems proceeds from this point depends on a number of factors, scientific, economic, and political. One important factor will be the availability of suitable propulsion systems to propel men and materials into outer space on specific missions of interest.

Many propulsion systems have been suggested numerous times for space operation; of these, three classes are considered in this paper: (1) chemical, (2) nuclear, and (3) ion rocket systems. The discussion considers typical engine configurations and some of the design requirements imposed on these propulsion systems by the peculiarity of the environment and the mission for which they are intended.

The comparison attempted is by no means intended to result in an obvious optimum choice of propulsion system for space flight. Too many of the factors needed for a complete comparative evaluation are still unknown or not known with sufficient certainty to be reliable for design purposes. Differences and obvious parallels between the different systems are brought out. An attempt is made to show that these systems very likely will not resemble the propulsion systems designed for terrestrial flight requirements.

This article has been updated and condensed by the author from the paper of the same title presented at the Space Propulsion Session, IAS 26th Annual Meeting, N.Y., January 27–30, 1958.

The author is Supervisor of the Preliminary Analysis Group of Rocketdyne Division.

TYPICAL PROPULSION SYSTEMS

The purpose of the propulsion system is to move the desired useful payload to a given destination in as feasible and as efficient a manner as possible. An artificial earth satellite is maintained in a circular orbit by precisely balancing the earth's gravitational attraction by centrifugal force produced by the satellite's tangential velocity. The kinetic energy behind this force is provided by the rocket propulsion system. In a like manner, the total impulse (and energy) required for movement of a space vehicle from the earth's environment (gravity field) to the moon or to other planets can be referenced in terms of the velocity increment required in the vehicle.

For journeys to our moon, it is only necessary to provide the velocity increment required to overcome the potential energy represented by traversing the earth's gravitational field between the initial starting point at the given radius from the earth's surface and the neutral point between the earth and the moon, at which point the moon's gravitational pull just balances that of the earth. Beyond this point the moon's field becomes more pronounced than that of the earth. The flight plan in the moon's vicinity will determine added vehicle velocity increments required in that portion of the flight. This velocity and gravitational variation are shown in Fig. 1 from reference 1.

One has the alternative of obtaining the required total impulse—i.e., vehicle velocity increase—through expulsion of large masses of material at low exhaust velocity or of expelling smaller amounts of mass at very high velocities. In chemical rockets, the use of high exhaust velocities is, in general, desirable as it minimizes propellant mass required for a mission. However, the specific propellant requirement is not

the only factor in determining desired engine configuration. For a given vehicle mass, the desired acceleration to be produced from the engine determines thrust and, together with exhaust velocity, determines required specific engine power as $P = {}^1/_2\, a v_{ex}$ (kw./lb.). The relation between these parameters (Fig. 2) is taken from reference 2. An exponential increase in specific power applied to the vehicle is desirable in order to maintain reasonable vehicle thrust to weight ratio (acceleration) as I_s is increased.

Chemical engines are capable of equivalent specific power production in the range of 10 to 100 kw./lb. of vehicle. With the available range of exhaust velocity, acceleration in the range of 0.1 to more than 10g's has been attained. The high end of the range results from use of high energy (temperatures) propellants and high combustion chamber pressures resulting in high heat rejection rates and high strength requirements, respectively. The trend to higher engine specific weights with higher energy, though small, is present.

The same trend is present with nuclear rockets. The specific energy range of nuclear rockets, though theoretically unlimited, is for practical reasons only slightly higher than available with chemical rockets, possibly up to 1,000 kw./lb. Since the exhaust velocities are only a factor of two or three larger, the practical acceleration range parallels that of the chemical rocket. With higher specific power, engine weights rise because of greater shielding and cooling requirements for reactor and overall system.

Ion engine systems increase in mass with specific power because of the resulting increased ΔT and/or size of components required. Practical specific powers between 0.01 and 1 kw./lb. appear feasible. Thus even with exhaust velocities one or two orders of magnitude higher than the chemical and nuclear rockets, accelerations of only 10^{-5} to 10^{-3}g's are possible. Higher exhaust velocities though requiring less mass of propellant can, in some cases, require a greater propulsion

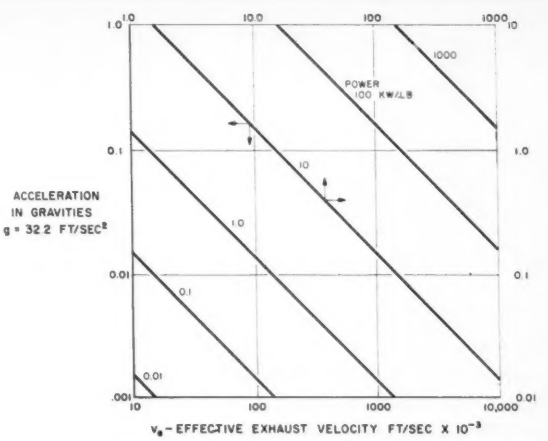

FIG. 2. Specific power requirements vs. exhaust and vehicle acceleration.

system mass. Thus, larger portions of missile dry mass will be devoted to propulsion system rather than to useful payload. Fig. 3 summarizes information relating to required vehicle velocity and vehicle mass ratio for missions considered in this paper. Superimposed are the ranges of mass ratio and exhaust velocity obtainable from the typical propulsion systems under consideration in this paper.

TYPICAL ENGINE SYSTEMS

Chemical Rockets

Liquid Propellant Systems—Liquid propellant rockets today are a developed and accepted means of propulsion. This type of engine utilizes liquid oxidizers and liquid fuels burning in a combustion chamber to release a large concentration of thermal energy. This combustion gas is expelled from the chamber at high velocity through a supersonic nozzle, the reaction from the momentum increase providing the push on the vehicle. A typical energy system of this type is shown sche-

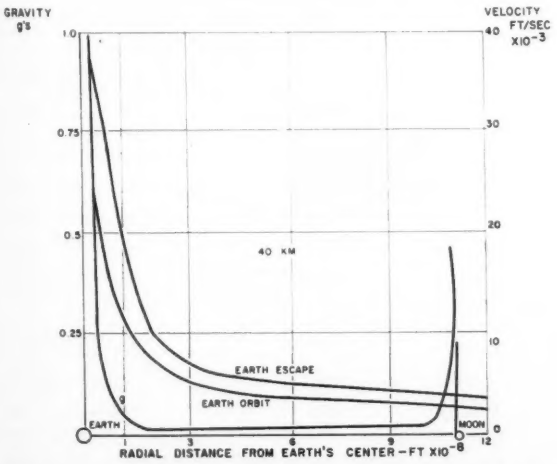

FIG. 1. Gravity fields and velocity requirements important to moon mission.

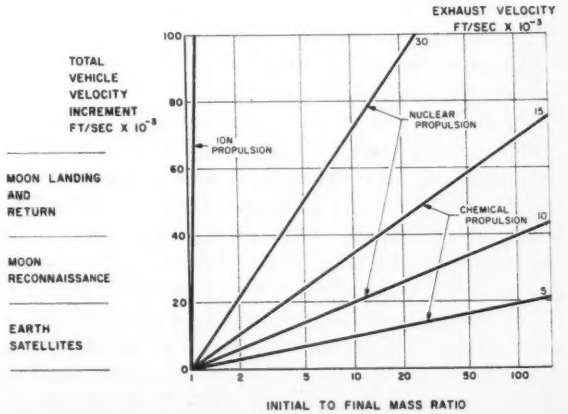

FIG. 3. Summary of space mission requirements.

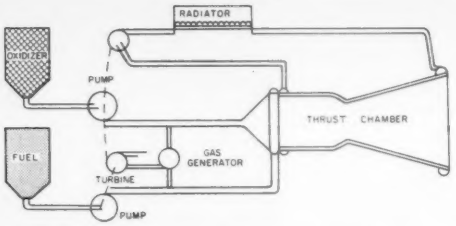

FIG. 4. Typical chemical rocket engine (liquid rocket engine schematic for space flight).

TABLE 1
Characteristics of Propulsion Systems*

	Typical working fluid	Maximum Temperature, F	Specific impulse sec, (altitude)	Ratio of thrust to engine weight
Liquid propellants	Fuel and oxidizer	4200 - 5700	200 - 300	50 - 80
High-energy liquid propellant	Fluorine hydrogen	7900	340 - 440	40 - 70
Nuclear energy	NH_3, He, H_2 H,N	3000 - 5000	400 - 1000	10 - 50
Ion propulsion	Cs, Rb	----	5000 - 20,000	0.0005 to 0.00005

* Based on reference 3.

matically in Fig. 4. A survey of the literature indicates that the currently favored propellants are oxidizers such as liquid oxygen and nitric acid compounds and fuels of the hydrocarbon family.

While these engines in their current state of development would be very excellent for a booster phase of space vehicle take-off from massive bodies, the relatively low specific energy (I_s) available results in extremely large total fuel consumption. This is reflected in the large mass ratios of space vehicles (Fig. 3). However, it appears that space missions of immediate interest such as one-way moon or Mars journeys can be accomplished now by engines of this type if sufficient effort is applied to the accomplishment of this task.

In order to minimize the amount of propellant required, the highest possible performance attainable will be sought for the above missions. Higher energy fuel and oxidizer combinations will be used. According to Tormey,[5] fluorine and hydrogen possess the highest performance potential of the chemical systems, followed closely by oxygen-hydrogen. Probable performance range is shown in Table 1 from Sutton.[3] The chemical engine performance improves with operating pressure because of resulting increased combustion temperatures.[5] Engine performance is characterized by the ratio of propellant gas temperature divided by molecular weight $I_s \propto \sqrt{(Tc/m)\,[F(\gamma)]}$. Dissociation of combustion products would further increase performance by decreasing effective molecular weight. However, at usual chamber pressure, dissociation requires increasing propellant temperatures considerably above that available from combustion. Reducing operating pressure will enhance dissociation, but gas temperature is lowered faster than molecular weight resulting in a net performance loss.

Solid Propellant Systems—Unlike liquid rocket engines, high-performance solid propellant rockets are only available experimentally in sizes ranging from a few hundred to many thousands of pounds thrust in single units. In the solid rocket, oxidizer and fuel are premixed and usually cast in solid phase in the engine. The propellant "grain" is consumed by burning on the surface to create the gas for expulsion. The solid system is considered by many to be simpler in operation than a liquid system. Relative ease of altitude starting of solid engines may be an advantage in space propulsion if propellant temperature sensitivity can be overcome. Although the performance (I_s) is considerably less than that potentially available from the liquid systems, the smaller number and complexity of engine parts in the solid engine may make the solid propellant system worthy of consideration for less ambitious space propulsion.

Nuclear Rocket Engines

Consideration of nuclear rocket engine requirements discussed by Clarke, Shepherd & Cleaver, Seifert, Rosenblum, et al.[1, 2, 6–8] provides an indication of the typical form initial engines of this type will take. A typical layout is shown in Fig. 5 (from reference 8). In this system potentially unlimited quantities of thermal energy are generated in a suitable high temperature reactor core. The heat is transferred to a propellant passing through the porous core after which the propellant is expanded in a nozzle to produce the desired thrust. The requirement of only one propellant is a great simplification of the engine system which is counterbalanced by the complexity of the reactor.

Any fluid not adversely affecting core neutronics can be used for propellant. If the core can heat the propellant to temperatures comparable to chemical combustion temperatures (over 4,000 F.), the best performance improvement attainable, using molecular hydrogen, is about twice the highest chemical engine performance (Table 1). On this basis, the system mass ratio can be reduced between factors of 2 to 100

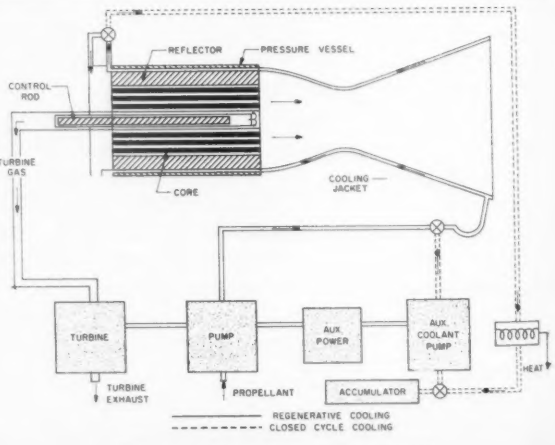

FIG. 5. Dual thrust nuclear rocket.

compared to that of a vehicle powdered by the best chemical engines (Fig. 3). The mass of core and other extra equipment will have to fall within the added available dry mass of the nuclear powered system, otherwise the added complexity of engine low temperature and low density propellant would probably prove to be much less attractive.

Clarke suggests that low-pressure nuclear devices, if operated at sufficiently high temperatures, could increase the exhaust velocity by using light gases such as H_2 which would break down into its atomic form and further increase I_s. If hydrogen were completely dissociated, the performance could be increased by another factor of 1.4. However, Sänger-Bredt[9] points out that energy given up to the confining walls of the nozzle by monatomic gases will be excessive, even possibly prohibitive. This is due to the high heat fluxes involved; hydrogen and helium atoms have mean free paths so long (on the order of feet) that no effective cool gas boundaries can be produced on the metal walls.

Any system based on the fission process produces high energy particles which are destructive to both materials and humans, to varying degrees, through mutation and/or heating. Thus, manned space flight systems using nuclear rockets will require extensive shielding systems which will add markedly to engine system weight. In space propulsion, where no air scattering need be considered, shadow shielding is most economic. Simplified, optimistic calculations of shield requirements were made based on a nuclear engine expending energy in space sufficient for a 100,000 lb. payload moon reconnaisance without landing, following methods of Glasstone and Calkins.[10, 11] The results indicate that a shadow shield for a 6-ft. diameter cylinder 100 ft. from the bare reactor core will require shield masses of the order of 10,000 lbs. for humans and 100 lbs. for critical material components. These figures are only indicative of masses involved and may be low by an order of magnitude or more when related to specific system designs.

In summary, it appears that the nuclear rocket, based on a reactor core heating a fluid propellant, appears feasible and capable of providing vehicle performance two or more times as high as the best chemical rockets, thus requiring lower mass ratio vehicles and fewer stages. However, the development will require a very large effort compared to chemical rockets and vehicle handling, and launching problems may be prodigious due to the health hazard involved. Again the overall engine mass may detract considerably from the application to a space system by restricting the useful payload of a given system.

Ion Rockets

The third propulsion system to be considered for space applications is the ion rocket. As described in references 15, 16, and 17, the exhaust jet, which is energized sufficiently to ionize the gas completely, is accelerated to very high velocities by an electric

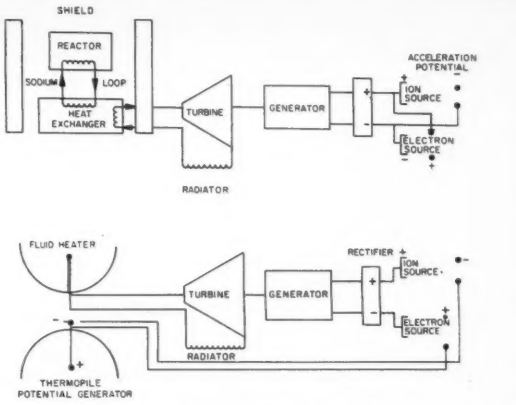

FIG. 6. Typical ion rockets. (*Top*—Nuclear-powered ion rocket engine schematic. *Bottom*—Solar-powered ion rocket schematic.)

field. The mass of propellant required is thereby minimized. Typical systems are shown in Fig. 6. These systems require an energy source to ionize and accelerate the jet particles. To minimize chances of space charge buildup on the vehicle, the ions and electrons stripped off must both be expelled at conditions which insure recombination immediately behind the vehicle.

Ion Source—There are many possible materials available for ionization from gases (H_2, He, N_2) to solids (Ce, Rb). The choice of method of ionization is open, depending on the ionization potential and system compatibility. Some low potential elements can be ionized by boiling. Some work best when vaporized from a target anode by electron bombardment, and some require very high energy arc discharges for efficient ionization. In addition to ionization method, the choice of material also effects the accelerating potential and power requirement. The thrust in this system is given by $F = P\sqrt{2m/Eq}$. For a given thrust requirement the use of heavy ions minimizes power—i.e., power-plant mass—and accelerating potential requirements—i.e., momentum $= m\ (\Delta v)$.

Power Source—Several power sources are conceivable. A closed-cycle nuclear power plant appears feasible as discussed in reference 15. The system may be based on either closed gas or condensing liquid power cycles. The power capacity will probably be limited by size of the radiator used for heat rejection. Radiator size requirements determined during studies by Rocketdyne from the Directorate of Advanced Studies, AFOSR, result in a range from 1,000–5,000 sq. ft. minimum surface requirement per megawatt of power output. The reactor power and temperature level and the thermodynamic cycle efficiency affect the radiator size requirement as shown in Fig. 7. Power-plant component masses for a typical system may be small, individually, compared to the radiator mass if the radiator construction results in masses of even 1/2 lb. per sq. ft. of surface. Turbogenerator and rectification equipment for a few hundred kilowatts should

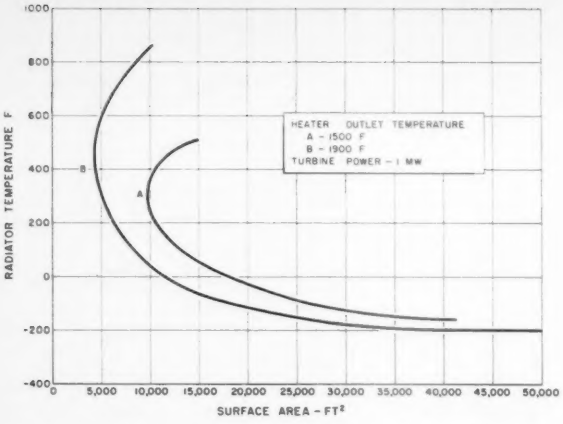

FIG. 7. Typical radiator area vs. minimum radiator temperature.

weigh only 2 to 3 lbs. per kw. each. Here again reactor shield requirements will add to the engine system mass; the shield requirements will depend on power level and duration as well as proximity of components to the reactor core.

The use of solar energy also has attractive features for ion propulsion in space. In a typical system, large reflectors concentrate the 1.4 kw. per sq. m. radiant energy available from the sun (in the earth orbit) and convert the energy into power. Ehricke[16] proposes interesting spherical reflectors for heating a working fluid. The radiation may also be concentrated on thermopiles for direct conversion to electrical power. However, while large potentials in the 10,000 volt range can theoretically be built up in this manner, only potentials in the 200 to 400 volt range are reported in the literature. Also, only relatively low power is available due to practical current limits of thermopiles. This system might, with further development, be suitable for electrostatic portions of a propulsion system. The use of solar batteries is also a possible means of direct conversion of solar into electrical energy. All the systems discussed suffer from the poor conversion efficiency of the available solar energy which, according to published data, varies from 2 to 10 per cent. As Ehricke points out, this poor conversion necessitates reflectors hundreds or even thousands of feet in diameter, taxing the designer's skill to arrive at a practical system.

In summary, the ion rocket appears very interesting for space flight which is the only feasible regime for this system. Increases in power-plant (especially solar energy conversion) efficiency will increase the potential of this system. Currently the problems of reflector assembly, control, and long-time reliability make the solar heat system somewhat less attractive as the power source for ion propulsion than a nuclear reactor.

ENGINE COMPARISON

Before attempting to compare the propulsion systems just described and to discuss design requirements peculiar to space operation, it is desirable to define the missions and environmental conditions in terms of which these propulsion systems are to be considered.

Mission

The unmanned free-flight satellite is in existence. The next logical step would appear to be the development of larger manned satellites provided with small propulsion systems so that their trajectories may be varied or, conversely, may be held constant for very long durations by providing the small impulse necessary to counteract drag and other error producing effects.

Next, one logically considers unmanned and then manned space ships for exploration of the moon. Unmanned exploration of the moon will precede the development of large manned earth satellites due to the probable extreme expenditure involved in the latter undertaking. The unmanned exploration of the moon will probably embody three phases accomplished in rapid sequence. First, a missile will be crashed on the moon without regard to its destruction, so that decelerating propulsion systems need not be considered. Next will be circumnavigation of the moon, wherein the vehicle is set on a trajectory such that the moon's gravitational field is employed to turn the space ship about the moon and return it toward earth to its initial starting orbit. Finally, successive steps will involve placing a satellite in an orbit about the moon and then landing a manned mission on the moon.

Environment

It is now possible to define certain important environmental conditions which will have varying degrees of influence on the design of propulsion systems for these space missions. First, as noted in Fig. 1, at distances greater than 25,000 miles above the earth, the gravitational attraction between a space vehicle and earth is less than 1 per cent of that on the earth's surface. Therefore, at greater distances from earth, the manned satellite or space mission to the moon will operate in an essentially gravity-free environment, in which changes in the vehicle acceleration equivalent to even 1 or 2g's will be strongly felt by the vehicles, and their contents.

No atmosphere (air) is assumed to exist, thus any air drag with the accompanying aerodynamic heating need not be considered. The normal atmosphere is replaced by a distribution of particles in space made up largely of low-pressure hydrogen ions, some helium, and a few heavier particles generally defined as meteors. According to Shepherd[6] this "hydrogen" gas exists in space at an equivalent average density of about one atom per cu.cm. Apparently this hydrogen gas is of insufficient density to have any influence on the motion of a ship through space unless the vehicle were traveling at a speed in excess of 150,000 ft./sec. Therefore, this environmental condition need not be considered further if current knowledge is correct on this point.

In addition to the hydrogen gas occupying space,

one must take due account of the meteoric particles and dust which permeate space. Astrophysical studies indicate that they comprise about 1 per cent of the total mass occupying interstellar space. Table 2, extracted from Sanger,[18] indicates the distribution of the larger meteoric particles in space, together with the energy distribution in these particles, their size, and probability of encounter by a 3-m. diameter sphere in a 24-hour period. All of the references cited are in general agreement that on space flights of reasonable duration probability of encountering a large meteor particle which could do physical damage of critical nature to a space vehicle is rather remote. The slight probability of encounter with a lethal meteor is important in manned space flight, however.

Based on information presented by Sanger[18] it appears that the smaller submicrogram meteor showers may well have a significant erosive action on the surfaces of the missiles. Erosion rates of up to 0.005 inches in 1/2 hour are estimated. Sanger also discusses the possibility of sputtering effects due to the high electrical energy potentials of space dust protons striking surfaces constructed of metals having low sublimation energy. However, he concludes that all of the metal usually considered for propulsion and missile systems have threshold energies considerably above those possessed by the interstellar particles and therefore would not be prone to destruction by sputtering.

One must also consider radiation, both particles and wave types. According to recent articles by Korff and Shepherd,[19, 20] the cosmic radiation intensity found in outer space is many times that which penetrates the atmosphere to be detected on the earth's surface. Cosmic rays are thought to consist of 79 per cent hydrogen nuclei (protons), 19 per cent helium nuclei (beta particles), with 1 per cent heavier particles—up to the iron nucleus—included in the system. The energy levels in the cosmic rays are distributed between 10^8 and 10^{20} electron volts, while the intensity of these rays is about 100 to 200 protons per cu.cm. of space. Rossi[21] indicates a distribution of energy in cosmic rays of inverse cubic power so that the average energy level of a cosmic particle shower is probably between 10^9 to 10^{12}. These energy levels are very high in comparison to that possessed by neutrons released from nuclear reactors, although the integrated dosage appears to be one to five orders of magnitude smaller than would fall on a vehicle payload from a nuclear or ion rocket reactor for the missions considered in this paper. Nonetheless, cosmic rays must be considered as having an influence on vehicles designed for space. Very little is known of these particles at present. As Schaefer[22] points out, if the showers contain significant proportions of heavier lower energy particles, they will be quite lethal for humans in space and will require shielding of vehicles. However, if the lighter particles predominate, some space biologists think it may be better to leave shields off or at least design them specifically for cosmic rays rather than fission particles. The slowing down of cosmic protons creates large numbers of ionizations within the slowing down material and in certain materials may produce more harmful secondary emissions than if allowed to go through the vehicle uninhibited. Magnetic field shields might be considered, but, because of the particle energy involved, prohibitively large field strengths would be required. The cosmic particles and magnetic field may act to further disrupt communications and guidance and thus further increase equipment complexity and auxiliary power requirements. Much more must be learned of this subject before it can be considered quantitatively in regard to space propulsion.

TABLE 2
Data Concerning Meteoroids and Their Penetrating Probabilities

Meteor visual magnitude	Total kinetic energy, ergs	Mass, gram	Radius, cm	Probability encounter, 24 hr	Penetration in Al, cm
0	1.0×10^{13}	1.25	0.46	1.2×10^{-8}	10.9
1	4.0×10^{12}	0.50	0.34	3.1×10^{-8}	8.0
2	1.6×10^{12}	1.98×10^{-1}	0.25	7.7×10^{-8}	5.9
3	6.3×10^{11}	7.9×10^{-2}	0.18	2.0×10^{-7}	4.3
4	2.5×10^{11}	3.1×10^{-2}	0.14	4.9×10^{-7}	3.2
5	1.0×10^{11}	1.2×10^{-2}	1.0×10^{-1}	1.2×10^{-6}	2.3
6	4.0×10^{10}	5.0×10^{-3}	7.4×10^{-2}	3.1×10^{-6}	1.7
7	1.6×10^{10}	2.0×10^{-3}	5.4×10^{-2}	7.7×10^{-6}	1.3
8	6.3×10^{9}	7.9×10^{-4}	4.0×10^{-2}	2.0×10^{-5}	0.93
9	2.5×10^{9}	3.1×10^{-4}	2.9×10^{-2}	4.9×10^{-5}	0.69
10	1.0×10^{9}	1.2×10^{-4}	2.2×10^{-2}	1.2×10^{-4}	0.51
11	4.0×10^{8}	5.0×10^{-5}	1.6×10^{-2}	3.1×10^{-4}	0.37
12	1.6×10^{8}	2.0×10^{-5}	1.2×10^{-2}	7.7×10^{-4}	0.27
13	6.3×10^{7}	7.9×10^{-6}	8.6×10^{-3}	2.0×10^{-3}	0.20
14	2.5×10^{7}	3.1×10^{-6}	6.3×10^{-3}	4.9×10^{-3}	0.15
15	1.0×10^{7}	1.2×10^{-6}	4.6×10^{-3}	1.2×10^{-2}	0.11

In addition to the high energetic radiation, one must also be mindful of the influence on space propulsion of direct thermal radiation from the sun which, in outer space at the same distance from the sun as earth, has a normal intensity of about 1.4 kw. per sq. meter of intercepted surface. This radiation (pressure force of 4×10^{-11} psi as well as energy source) may or may not be desirable in connection with the propulsion systems just discussed but must be taken into account as a primary environmental consideration.

Design Considerations

Mission Requirements

The extremely high flight velocities required for moon reconnaissance and more ambitious missions have been indicated in Fig. 3 and Table 3.

As noted previously, velocities of these magnitudes require mass ratios of 50 or greater for chemical rockets, 4 to 10 for nuclear rockets (fusion systems excepted), and 1 to 2 for ion systems.

The best available rocket-powered vehicles appear to have design-limit mass ratios (initial to final vehicle mass) in the range of 5 to 10 per stage. Thus chemical rocket-propelled systems will require many stages to accomplish the moon missions. Nuclear rockets may well be able to do the entire job with single stage,

XUM

TABLE 3
Vehicle Velocity Increments Required for Various Moon Missions

Crash-land, payload on moon	36,400 ft./sec. or greater**
Circle moon with payload and return	36,400 to 36,700*
Land payload on moon	44,000 ft./sec. or greater**
Land on moon and return	51,700 ft./sec. or greater**

* Earth escape velocity.
** Figures given neglect any losses and trajectory errors requiring compensation.

which offers the attractive advantage of vehicle simplicity. Ion rockets appear capable of easily handling the space propulsion job once the vehicle is orbiting about the earth or otherwise boosted to a sufficiently high velocity that its low acceleration capability can be utilized. As the missions become more ambitious, the ion rocket will be more attractive. In addition to these system characteristics, desire to keep the space vehicle within reasonable size would suggest that a boost system be employed to provide a significant portion of the required total velocity increase in the case of any space propulsion system.

Thrust Level and Operation

Because of the difficulty experienced attaining precise terrestrial navigation and guidance, it appears that all space vehicles will require propulsion systems capable either of continuous or intermittent low acceleration thrust for correction of course errors, as well as the minute possibility of altering course to avoid collision with a lethal space particle. Leisurely take-off from an orbit would certainly give more time for accurate initial orientation of the vehicle on its intended course. Large overshoot in velocity increment or poor navigation will require significant additional thrust and propellant consumption which could be fatal to the success of ambitious missions already pushed to the limits mass ratiowise.

Consideration of the sensitivity of the vehicle and its components (delicate instruments or humans) to apparent gravity changes from acceleration rate changes would seem to make low acceleration continuous propulsion desirable in space. While humans can tolerate 6*g* acceleration changes for short periods and most instruments considerably more load, the effect of such loads on both is undesirable for efficient vehicle and payload performance and design requirements. It seems very desirable to maintain artificial gravity (1*g*) conditions in the manned ship at all times by slow spin or other suitable motion. Any propulsion or other force applied to the ship might alter the motion or change course so that continued power for the artificial gravity may well be required.

These arguments seem to the writer to point to the desirability of low long-duration thrust for space flight. Indeed one might consider the engines as very large scale vernier systems. All three propulsion systems under discussion can be designed to operate in this fashion. The liquid chemical rocket with hypergolic propellants can be started and stopped at will and is thus adaptable to either continuous or intermittent operation. Low thrust results in small lighter-weight engines. Solid rockets could accomplish the low thrust intermittent operation but with more difficulty (environmental storage and low temperature starting) and less precise control.

The nuclear engine and nuclear powered ion engine are best suited to more *continual operation*, at least of the power source. Any complete shutdown of reactors requires relatively long cool-down periods with coolant flow before they can be left in safe radiation equilibrium. Starting and stopping of these engines required relatively complex procedures which must be carefully coordinated with the vehicle flight program. In addition to reactor power build-up rate limitations which are inherent in a reactor design and cannot easily be altered, the poison build-up on shutdown may make the engines inoperable when urgently needed. However, the reactor's residual shutdown power quickly decreases to a few per cent of reactor rated power. The engines thus might well incorporate a bypass fluid system for supplying the auxiliary power to the vehicle on a continual basis and thus be in a position to produce full power intermittently when called on to do so.

The solar powered ion rocket is equally feasible for intermittent or continual low power operation. In this case, the solar collector would probably be oriented, as required, to limit power as it is most important to keep the "heat sink" radiator size at minimum. This orientation of very large collectors (and radiators) must be done slowly and symmetrically, otherwise additional effort and propellant expulsion will be required to regain the desired course.

Shielding

Consideration of the shielding requirements also suggests relatively low power operation of nuclear reactor powered propulsion systems. As discussed previously, minimizing total power expenditure will tend to minimize shield requirements, especially in manned vehicles. The shadow shield thickness varies with leakage energy intensity which decreases roughly as the square of the distance from the reactor core. Any shield required around the core proper also would be minimized as to mass with the smaller low power reactor, since a given spherical thickness of shield decreases with core radius.

All of the above considerations, as well as those to follow, seem to apply also to manned satellites.

Environment

The effect of erosion by interstellar dust appears to be sizeable enough to require consideration. This factor will suggest: (1) minimizing time in space between terminal points and (2) design of engines with minimum surface to be eroded. On long space journeys, the difference caused by low or high thrust will probably not increase the time of transit sufficiently to affect

design. The minimum surface idea points to low thrust engines again, and favors chemical rockets. The solar ion system is at a distinct disadvantage in this respect. Thus, space propulsion systems using radiation heat rejection will probably be fabricated of materials most efficient, strengthwise, at high mean temperature (800 to 1,600 F.), possessing low emissivity (except for radiators), and exhibiting tough erosion resistance properties. Potential particle penetration may require that the propulsion system be housed by a protective shell, and tank and radiator systems be compartmentalized to minimize leakage losses from any such penetration. As an alternative, manned vehicles may consider repair of low-probability punctures. Unmanned vehicles may be written off as failures if punctures occur in a vital part during a mission. Cosmic ray shielding, if provided in vehicles, will not be the same as that designed to absorb reactor neutron leakages. A shadow shield is sufficient in one case while total coverage is required for cosmic ray protection. Engine design will probably avoid materials such as plastics, rubbers, etc., which are adversely affected by very high energy protons. This may result in considerable design variation from current practice.

Design Concepts

Chemical Rockets—Low-thrust high-performance chemical engines may be difficult, if not impossible, to cool satisfactorily with propellant alone. However, a separate radiant sink coolant system might solve this otherwise difficult problem, even though some 1/4 to 1/2 per cent of the badly needed propellant energy would thereby be lost. Such a system, as shown in Fig. 4, might allow operation at more optimum conditions to make up for the small unrecovered energy loss to the coolant. The radiator area needed to handle the heat load from a chemical engine capable of the same mission as a 1-megawatt nuclear system of 30 per cent cycle efficiency is one third or less of the areas shown in Fig. 7, depending on chemical engine thrust level (and acceleration) employed.

Nuclear Rockets—The above radiation sink cooling system might be applied to nuclear rocket systems to cool critical non-nuclear parts. Here the small energy loss would not be critical.

For any reactor design there is some minimum reactor volume from criticality consideration. It may be that one core could supply the high thrust for boost and then switch to more moderate thrust operation in space using the separate coolant system to protect shell and other critical parts. Propellant flow rate will probably be insufficient to cool the entire engine system under these conditions, as well as during shutdown of the system. Such operations (Fig. 5), if feasible, would enhance the overall attractiveness of the nuclear propulsion system.

Ion Rockets—The ion propulsion system, while producing large thrust per unit of propellant expelled, may not carry as large a useful payload as I_s might indicate. The separate power source as discussed is bulky, massive, and probably difficult to assemble in space. Ingenious design will be required to minimize required radiator area, mass, and erosive surface. Cycle efficiencies below the optimum may result in minimum power-plant mass as low efficiency allows higher temperatures in the radiator and thus greater radiator effectiveness.

In order to minimize the power-plant mass, the efficiency of each component must be pushed to the utmost of its capabilities. High-mass, low-ionization potential propellant (cesium, rubidium) probably will be used to minimize potential and power requirements in the ion engine systems. High operating temperatures and minimum pressures are desirable in the power system with emphasis placed on use of maximum hot-strength materials in the power-plant construction.

The solar energy collectors, while extremely large in area, as shown by Ehricke and others, need not be massive. However, very thin, balloon-like structures, while light, will be subject to destruction by erosion, punctures, and radiation deterioration, especially if compartmentalizing is not employed. It is not clear that reliability can be achieved without the use of self-sustaining reflector design.

As a result of these massive power-plant components, there is some minimum size for each mission below which no usefully large payload can be transported. Much more experimental development of power-plant components is required before the best power level and acceleration ratio can be established for ion rocket power and space missions.

Conclusions

This evaluation and comparison has touched on only a few features relating to a portion of possible space propulsion systems. However, insofar as the discussion holds, the following points may be made:

(1) All systems discussed can, with suitable effort, probably be used to pursue successfully the space missions described in this paper.

(2) Too many unknowns still exist to determine the best engine system. With further development both the nuclear and ion systems may prove superior to chemical systems for space missions. They have greater potential than chemical rocket engines considering the relatively crude development state both systems are in at present.

(3) Moderate thrust operation of all the engine types appears preferable.

(4) The engines will be considerably different in concept from terrestrial-bound systems both in design and in materials used in engine fabrication.

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(*Continued on page 52*)

Allan Bernhardt

AIR SAFETY

Flight Safety Foundation's Ninth International Seminar Studies Collisions, Landing Mishaps, Fire, Air-Sea Search and Rescue, VTOL Safety, and Jet Transport Pilot Training. Edward Curtis, George Tryon Honored; Eight Sessions Feature 37 Papers.

SIGNIFICANT problems still to be solved in making flight safer were debated, and safety progress was reviewed and demonstrated at the 1957 Flight Safety Foundation International Seminar in Palo Alto, Calif., on November 11–15.

The event was held in cooperation with the Coast Guard, the USAF Military Air Transport Service, and the Navy. The ninth such conference of the Foundation, it was hailed by more than 250 air safety experts from this country and abroad as one of the most informative ever staged.

During 5 full days, delegates, attended eight technical sessions, participated in an exercise aboard the USCG Cutter "Gresham," and saw four persons honored at the Seminar dinner at which Col. John Stapp was guest speaker. The Air Force's "bullet man" discussed "The Very High Altitudes Beyond the Earth."

Panel discussions were held on Human Factors, Seat Design, and Design Safety Engineering. These were conducted, respectively, by Dr. John Poppen, A. Howard Hasbrook, and C. O. Miller.

By group, those attending represented eleven airlines, 40 manufacturers of aircraft and aviation equipment, 18 commands of military services, 20 Government and private aviation organizations, and experts from research centers in the United States and eight other countries.

The Foundation's awards for distinguished service in achieving safer utilization of aircraft were presented by Jerome Lederer, Managing Director of the Foundation. Recipients were Edward P. Curtis, Vice-President of Eastman Kodak, and George H. Tryon III, Secretary of the Aviation Committee, National Fire Protection Association. These awards are presented on behalf of *Aviation Week* magazine.

Awards of Merit went to Max W. Landis and Raymond G. Chase, CAA Air Traffic Controllers, of Santa Barbara, Calif.

Mr. Curtis, a major general in the USAF Reserve, was honored for his report to President Eisenhower on Aviation Facilities Planning, which included "A Plan for Modernization of the National System of Aviation Facilities." In presenting the award, Managing Director Lederer observed that Mr. Curtis' report "gives to aviation the recognition of its place in society it has long deserved."

One of two FSF Awards for 1957 honored Edward P. Curtis for his report to President Eisenhower on Aviation Facilities Planning. J. Gordon Bennett, Staff Director, Bureau of the Budget, is shown (*left*) receiving the plaque for him from Jerome Lederer, Managing Director of the Foundation.

Mr. Lederer, in presenting Mr. Tryon's award, saluted him as "an international authority on aviation and airport fire protection." The citation with the award said of the recipient in part: "His courage and persistence in the face of difficulties that appeared insurmountable in the early days of his efforts have resulted in many fire prevention and fighting practices now widely accepted by the aviation industry. These include methods for rescue and fire fighting, fueling equipment and methods, and the dissemination of information on all phases of aviation fire problems."

The two CAA traffic controllers received their awards for quick thinking and close attention to duty, thereby saving the lives of a small plane pilot and his passenger. The pilot, using a flashlight to augment inadequate cockpit lighting, read an approach chart incorrectly and would have crashed into a mountain if Chase and Landis had not discovered his error.

Indicative of the most significant problems facing aviation safety today were titles of the Seminar's eight

Mr. Bernhardt is Associate Editor of the *Review*.

technical sessions. These were Search and Rescue, Survival, Evacuation; Mid-Air Collision Problems; In-Flight and Crash Fire Protection on Turbine-Powered Aircraft; Vertical Flight; Intra-Company Communications, etc.; The Last 200 Feet—Progress in All-Weather Flying; and Some Critical Jet Problems.

Aboard the "Gresham," the Coast Guard demonstrated its Search and Rescue Service procedures including night water landings with illumination, with and without aircraft assistance; aircraft self-illumination; and radar guidance. Other demonstrations showed conspicuity of new markings for life rafts and a flashing marker light, the United Air Lines new position light, an inflatable ring buoy, inflatable rafts, operation of a rescue metal cutting saw, and the Navy's technique in crash fire fighting and in extinguishing a magnesium fire.

Inquiries about the discussions presented during the Seminar may be directed to the Flight Safety Foundation, 468 Fourth Avenue, New York 16, N.Y. A list of the sessions and presentations, prepared from a report by Otto E. Kirchner, of Boeing Airplane Company, follows:

Search and Rescue, Survival, Evacuation

(1) A Coast Guard Briefing on Search and Rescue. (Several papers unavailable during Seminar.)

(2) "Design of Exits," by John A. Roebuck, Jr., Douglas Aircraft Company, Inc.

(3) "An Experimental Study of Escape and Survival in Aircraft Ditchings," by Barry G. King, CAA.

(4) "Radio Beacons for SAR Operation," by Charles Urban, of Simmonds Aerocessories, Inc.

(5) "Water Survival Equipment," by J. Silverston, of P. Frankenstein & Sons.

(6) "Air Aspirated Life Rafts," by John Avellar, for Air Cruisers, Division of The Garrett Corporation.

(7) "Electronic Communications Devices," by D. M. Hilsabeck, of Wright Air Development Center.

Mid-Air Collision Problems

(1) "A Review of the Problem," by William Littlewood, of American Airlines, Inc.

(2) "Mid-Air Collisions in the USAF," by Anchard F. Zeller, USAF.

Colonel John P. Stapp, USAF, is pictured during his address before the Seminar Dinner assembly. At his left is Adm. John H. Cassady, USN (Ret.), Foundation President.

Tricky small boat handling gets attention from all hands during an exercise for Seminar delegates aboard USCG Cutter "Gresham."

(3) "Infra-Red Proximity Warning System," by R. D. Foley, Aerojet-General Corporation.

(4) "Aircraft Lighting Systems," by John M. Tillman, United Air Lines, Inc.

(5) "Wing Tip Anticollision Lighting," by H. W. Atkins, Atkins Light Corp.

(6) "Be Seen and Be Safe," by P. J. de Groot, Switzer Brothers.

(7) *The Growing Problem of Mid-Air Collisions*, a Flight Safety Foundation publication made available at the Seminar.

In-Flight and Crash Fire Protection on Turbine-Powered Aircraft

(1) "Electrostatic Fuel Hazards," by I. Irving Pinkel, NACA.

(2) "Fire and Collision Research Continues," by Alan L. Morse, T.D.C., CAA.

(3) "In-Flight and Crash Fire Protection on Turbine-Powered Aircraft," by Robert A. Dickson, Walter Kidde & Company, Inc.

(4) "The Aircraft Fire Fighting and Rescue Program in the U.S. Navy," by Carl Dreesen, Fire Protection and Crash Fire Equipment Engineer.

Vertical Flight

(1) "A Review of the Military VTOL-STOL Program," by Lt. Col. John L. Klingenhagen, Office of Secretary of Defense for Research and Development, presented by Col. James Wells, Army Aviation Safety Division.

(2) "Tilt Wing Propelloplane VTOL Aircraft," by J. B. Nichols, Hiller Helicopters.

(3) "Work Information to Get Action," by Leslie H. Matthies, Hallamore Electronics.

(4) "Altimetry," by Melvin Gough, NACA.

(5) "Safety and Economics," by Maurice Rappaport, Stanford Research Institute.

Intra-Company Communications, Etc.

(1) "AGARD's Views About Flight Safety and Pilot Selection," by Médecin Général P. Bergeret, AGARD.

(2) "Some Recent Advances in Communication Techniques," by Ray L. Leadabrand, Stanford, Research Institute.

(3) "Hazardous Cargo," by Edward A. Tappe, ALPA.

(4) "Random Pattern Landing-Gear Counter," by Comdr. J. A. Scholes, USN.

(5) "The Runway Friction," by Melvin Gough, NACA.

THE LAST 200 FEET—PROGRESS IN ALL-WEATHER FLYING

(1) "Accomplishments Since 1956 FSF Seminar," by D. S. Little, American Airlines, Inc.

(2) "Review of USAF-SAC Progress in All-Weather Flying," by Col. Howard J. Fry, USAF.

(3) "Slant Range Visibility," by W. A. Jensen, American Airlines, Inc., on loan to ATA.

(4) "Review of CAA Accomplishments and Plans," by Robert Gates, CAA.

(5) "The Mirror Landing System," by Lt. Comdr. William B. Barrow, USN.

(6) "Navy All-Weather Return to Carrier Landing System," by Capt. E. L. Farrington, USN.

(7) "Recent Developments in Landing Approach Research," by George E. Cooper, NACA.

(8) "Instrument Integration," by William Lear, of Lear, Incorporated.

SOME CRITICAL JET PROBLEMS

(1) "The Selection and Training of Pilots for Jet Transport Aeroplanes," by E. E. Rodley, BOAC.

(2) "Jet Transition Observations," by Donald L. Leonard, ALPA.

(3) "Jet Tanker Transport Operation," by Lt. Col. Kenneth R. Rea, USAF, presented by Major E. E. Campbell.

(4) "N.Y. Port Authority—Safe for Tomorrow," by Herbert Fisher, Port of New York Authority.

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"Satisfactory instrumentation may well consist of U-tube barometers used in an area where the temperature is controlled very accurately."

Laboratory Pressure Measurement Requirements for Evaluating the Air Data Computer

A. J. Eberlein
Minneapolis-Honeywell Regulator Company

ELABORATE INSTRUMENTATION for static pressure measurement is required if an air data computer (ADC) is to be accurate to a ±0.25 per cent pressure altitude. One of the first steps necessary is to determine the accuracy required of this instrumentation. This is usually done in an arbitrary manner, depending on laboratory practice.

A widely accepted method of measuring such static pressures is with the use of a barometer. It is felt that commercially available barometers only partly fill the instrumentation requirements of a 0.25 per cent ADC.

Cost and elapsed time for each pressure determination are two items which increase rapidly as pressure measuring requirements become more severe.

Extensive development work is required of any company to provide satisfactory pressure instrumentation for an ADC, accurate to 0.25 per cent of pressure altitude. Many companies should take a good look at the accuracy of their pressure instrumentation. This applies to the customer as well as it does to the manufacturer.

Determination of Allowable Instrumentation Tolerances

Typically, the ADC required accuracy is 0.25 per cent of indicated reading, and it is also necessary that the ADC operate to at least 100,000 ft. Fig. 1 shows the output tolerance requirements for such an ADC in terms of inches of mercury versus altitude. At first glance, these values may seem relatively large. It must be remembered, however, that these are the output tolerance requirements of the entire computer.

In the laboratory, the output of an ADC cannot be controlled to a greater degree than the input pressure. It is, therefore, necessary to determine the relationship of the input to the output. A common arbitrary rule of thumb states that the tolerance of the input should be one-tenth of the output tolerance requirements, implying a relatively negligible instrumentation error.

If the ADC output requirements of Fig. 1 are reduced by a factor of ten (to determine instrumentation requirements), then tenths of a thousandth of an inch of mercury become important. This measurement is far beyond the capabilities of commercial barometers which may vary in accuracy between approximately 0.005 and 0.015 in. of mercury.

Another arbitrary approach which merits consideration on this type of instrumentation assumes that the uncorrected errors present in the barometers are composed of many indeterminate errors. The nature of these indeterminate errors fosters a further assumption that the summation of these errors will form a normal probability function. This same type of normal proba-

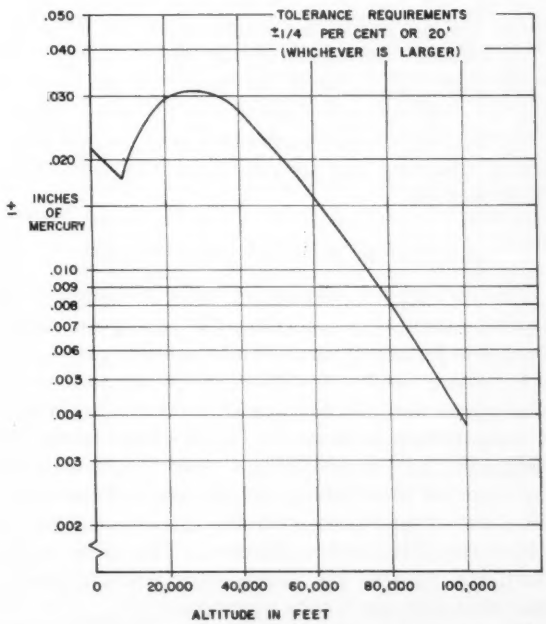

FIG. 1. ADC output tolerance requirements.

This paper was presented at the U.S. Navy Bureau of Aeronautics Symposium on Air Data, Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y., September 24–26, 1957.

Mr. Eberlein is Component Unit Supervisor in the Evaluation Department of Aero Division.

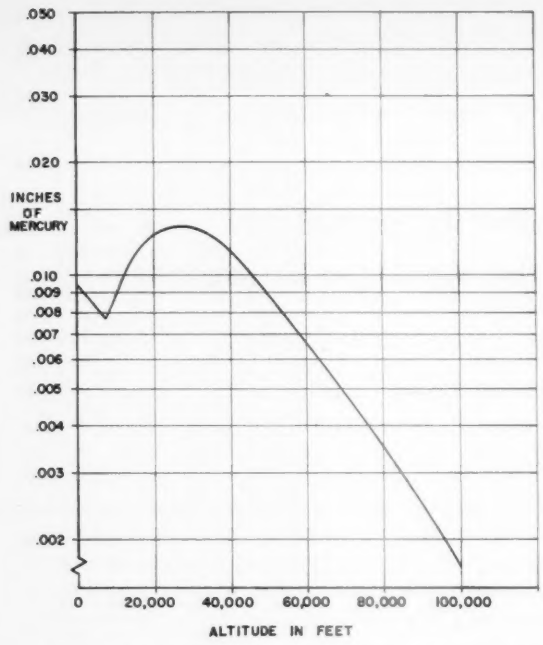

FIG. 2. ADC instrumentation requirements (pressure).

bility function will be formed by the indeterminate errors in the ADC. The two normal probability curves may then be combined on a root-sum-squares basis to make up the overall 0.25 per cent allowable ADC tolerance. For example, set the 0.25 per cent ADC tolerance error equal to ten units. Arbitrary assignment of 9 units to the computer allows 4.36 units for the instrumentation.

$$10 = \sqrt{(9)^2 + (4.36)^2} = \sqrt{81 + 19}$$

Using this approach and the above figures, Fig. 2 shows the instrumentation requirements for the ADC. (The value of the points on the curve of Fig. 2 are 0.436 times the value of the points on the curve of Fig. 1.) This range of values (0.0017 to 0.014 in. of mercury) represents requirements that may possibly be attained, assuming that sufficient money is spent on instrumentation.

BAROMETERS WIDELY USED IN INDUSTRY

The majority of barometers found in industry are of the cistern type. U tube barometers are found much less frequently in most laboratories.

To obtain results of ±0.010 in. of mercury, many precautions must be taken with a cistern barometer. A typical setup is shown in Fig. 3. Such associated equipment as vacuum pumps, cold traps, vacuum gages, special inert tubing (cobon), photoelectric readouts, and temperature-controlled areas are used in conjunction with such equipment. This same equipment, less possibly the photoelectric readout, is also associated with the U tube barometer.

When speaking of accuracy in regard to mercurial barometers, the statements of W. G. Brombacher of the National Bureau of Standards are most fitting:

"Contrary to the opinions held by many engineers and scientists, the portable barometer is limited in accuracy to about 0.1 mm. or 0.005 in. of mercury. This accuracy is obtained only if the bore of the tube is at least about 0.6 in., to reduce capillary errors, and if the barometer temperature is controlled or accurately known to well within 1° C. at the higher pressures, with a greater uncertainty permissible at low pressures." [1]

The errors which usually limit the accuracy of a cistern barometer are those due to thermal expansion of both the mercury and scale, surface tension effects, and inference of the level of the mercury in the cistern from that in the tube.

An estimate is made of the absolute accuracy of cistern barometers on the following basis:

(1) Density of mercury is corrected for temperature to the nearest degree Centigrade.

(2) Temperature stratification does not exceed 1°C.

(3) Corrections are made for the small pressures remaining on the vacuum leg of the barometer.

(4) The photoelectric readout system is checked for zero reading.

(5) The photoelectric readout is shaded from the effects of external lighting.

With these considerations in mind, the absolute accuracy of present equipment is shown on Fig. 4. Fig. 4 also shows the instrumentation requirements that have previously been presented on Fig. 2. From a visual comparison of the curves on Fig. 4, it may be readily concluded that cistern barometers are not satis-

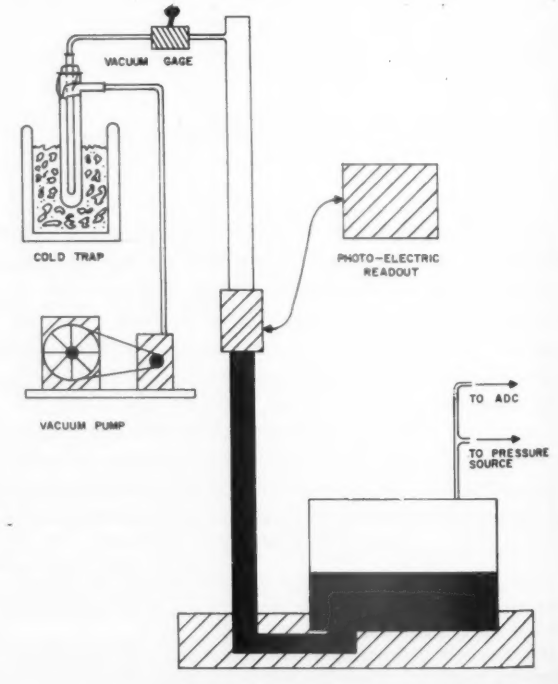

FIG. 3.

factory for the instrumentation requirements of a 0.25 per cent ADC.

The question which might logically follow such a statement would probably sound something like this: "What will satisfactory instrumentation for an ADC accurate to 0.25 per cent cost?" The answer is shown on Fig. 5. While cost-accuracy figures may vary (depending on whether the equipment is manufactured or purchased), the general trend is evident. This trend very clearly indicates that as absolute accuracy requirements become more severe, the point may be reached where cost may be one of the limiting factors.

Estimates of time-accuracy are also plotted on Fig. 5. The time necessary for each pressure determination increases rapidly as the absolute accuracy increases. The point may also be reached where the time for each pressure determination becomes one of the limiting factors.

For purposes of illustration, assume that a compromise is reached, and it is determined that an absolute accuracy of ±0.003 in. of mercury is sufficient. From Fig. 5, it is seen that it will cost approximately $5,000 per pressure source and require 10 min. per pressure determination. Assuming 150 pressure determinations per ADC, it will take a little over 3 days just to determine the pressures for a routine check of this device. Assuming that three pressure stations (two pressure sources each) are necessary to develop the device and that ten such stations are necessary to manufacture it, the instrumentation cost for pressure facilities alone will be approximately $130,000.

It is felt that the customer must carefully evaluate ADC accuracy requirements in terms of aircraft performance. While an ADC accurate to 0.25 per cent may be made, the aircraft (due to other errors present in the system) may not be able to utilize the full ADC capabilities. This decision then, in regard to the accuracy of the ADC, rests largely with the customer.

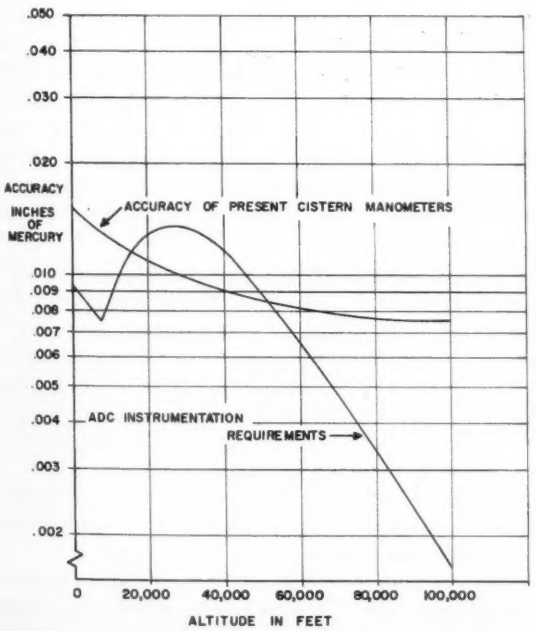

FIG. 4. Accuracy of present equipment.

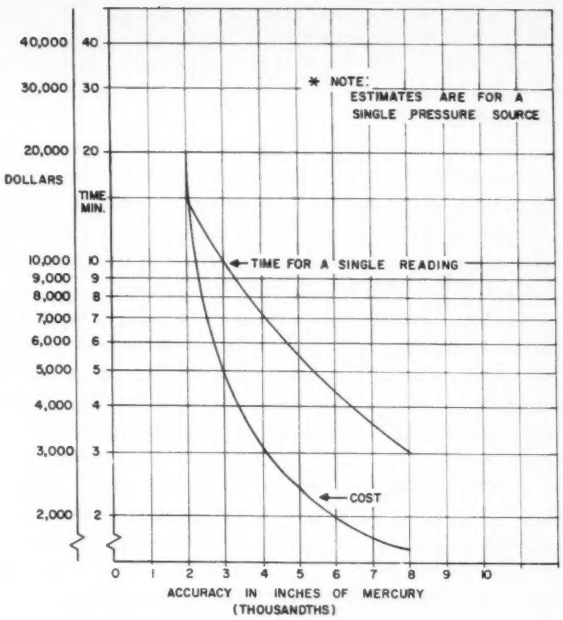

FIG. 5. Cost versus accuracy (estimated).

NOTES ON TECHNIQUES AND ASSOCIATED EQUIPMENT USED WITH BAROMETERS

A very important factor in the accuracy of barometers is temperature. It is very desirable to locate the barometers in a temperature-controlled area. The effect of temperature on a 30-in. column of mercury is shown in Table 1.

The temperature correction for mercury barometers with a brass scale is 0.000091 in. per in. of column height per °F. If an absolute accuracy more severe than ±0.007 or ±0.008 in. of mercury is desired, a U tube barometer should be used. When an absolute accuracy more severe than ±0.003 or ±0.004 in. of mercury is desired, it is extremely difficult to effectively measure the temperature along all parts of a mercury column and make the necessary corrections. Therefore, it is considered mandatory that the temperature be controlled to the proper value rather than correcting the height of the column of mercury for temperature variations. The National Bureau of Stand-

TABLE 1
Effect of Temperature on a 30-in. Column of Mercury

Temperature Change, °F.	Change in Column Height, In. Mercury
1	0.0027
2	0.0055
3	0.0082
4	0.0109
5	0.0136
10	0.0273
15	0.0410

ards published a pamphlet in June, 1951, *Corrections for Mercurial Barometers* which should be referred to for the technique of making gravity and temperature corrections.

The accuracy of any barometer will be seriously impaired if the mercury becomes contaminated with any type of impurity. The impurity will change the density of the mercury and will also change the shape of the meniscus. This change is caused by the impurity changing the surface tension of the mercury.

In the following paragraphs, two simple tests are given which may be used to judge the purity of mercury by visual inspection. These tests are far more accurate than any chemical method. It is stated that these tests are sensitive to as little as one or two parts in ten million.

A test recommended by Dr. Wichers[2] is in general use for testing mercury which consists merely of placing a globule of mercury in a clean porcelain dish and gently swirling it around. If it runs freely without leaving any tail, it has the necessary purity. The effectiveness of this test may be demonstrated on a qualitative basis rather easily. Take a clean globule of mercury and place a piece of solder in it for a period of 1 or 2 sec. At the end of that time, the mercury will readily tail.

The A.C.S. test[3] for base metals is similar. Ten to 20 gm. of mercury are evaporated on a hot plate without boiling, during which operation the mercury must retain its bright surface and not develop any film or scum.

The media transmitting pressure to the device being calibrated and to the barometer should be free of dirt and condensable vapor. Air which has been filtered and in which the relative humidity is controlled to a low value may be used for this purpose. Dry nitrogen is also considered satisfactory. When there are base metal impurities in the mercury, and oxygen is present over the mercury surface, oxidation occurs, leaving a black residue which adheres to the glass. This indicates that the barometer is contaminated and should be cleaned.

Referring to Fig. 3, note that immediately following the vacuum pump there is a cold trap which consists of a condensing flask submersed in a dry ice and acetone bath. (A suitable container is the type 820 thermos bottle made by the American Thermos Bottle Co.) There are at least three reasons for the cold trap:

(1) The cold trap condenses out the oil vapors from the vacuum pump. The low pressures necessary at the top of barometers are below the vapor pressure of the oil at the temperature at which the vacuum pump operates. The oil vapors diffuse into the barometer tube where they condense, forming black deposits. This condition makes it impossible for the photoelectric pickup to properly sight the meniscus top as the tube becomes virtually opaque. Mercury will adhere to the oily film on the tube wall and cause serious changes in meniscus shape.

(2) The cold trap condenses out water vapors in the system. Microscopic droplets of water on the tube wall is a major cause of mercury adherence to the tube. A meniscus may adhere to a damp surface to a point where it will become concave on a descending column and extremely high on an ascending column. This change of meniscus shape could result in an error of 0.050 in. or greater.

(3) Finally, the cold trap serves as a protection for the vacuum pumps. In the event a barometer overflows, the mercury will be trapped and frozen in the cold trap. If mercury gets into the vacuum pump, the pump will gradually deteriorate and finally lock.

During the operation of a barometer, it is necessary to see that air bubbles do not occur along the mercury column inside the tube. Three reasons for the occurrence of these bubbles are:

(1) If air is admitted to a cistern barometer too rapidly, it will be carried into the tube with the mercury. This may be prevented either by admitting air very slowly or by deflecting the air in the cistern so that it hits the cistern glass and not the mercury surface.

(2) When there is a high vacuum present on both sides of the barometer, the stainless steel barometer base may outgas. It is possible to reduce this effect by vacuum baking the stainless steel components of the barometers when they are cleaned.

(3) If a cistern barometer is transferred from one location to another, it may have been shaken up to the point where air has gotten trapped in the base. One of the ways to get rid of the air is to lay the barometer down so that all the mercury runs into the cistern. Evacuate the tube for approximately 30 min. Then place the barometer in a vertical position before removing the vacuum. The barometer is now ready for service.

It is necessary to give consideration to the type of tubing used in the vacuum and pressure lines going to the barometer. An inert clear plastic tubing such as cobon tubing is satisfactory for this purpose, as is stainless steel tubing. A clear plastic tubing has the added advantage of allowing a visual inspection thus ensuring a lesser degree of contamination. Ordinary black rubber tubing will disintegrate at low pressure and contaminate the mercury. It is not advisable to use copper tubing because mercury will readily combine with copper.

When making absolute pressure determinations, it is necessary to have one leg of the barometer at a high vacuum. A high vacuum pump (25 microns or less) such as a Welch Model 1400B or equivalent is satisfactory. It is necessary to subtract 0.001 in. of mercury for every 25 microns of pressure left on the vacuum leg of the barometer. It is, therefore, desirable to monitor the above pressure at all times throughout a test. A thermocouple type vacuum gage such as a Hastings Gage (Model DV-1) or equivalent is considered satisfactory for this purpose.

Many cistern barometers are equipped with photoelectric readouts. These devices determine the height of the mercury column by using the top of the meniscus and a photoelectric pickup. If the photoelectric pickup

is not well designed, ambient light in the room may cause a considerable error in readings. In the case of a 60-cycle photoelectric pickup being used in conjunction with 60-cycle (fluorescent) lighting, errors as large as 0.010 in. of mercury have been observed. In this case, it is necessary to provide extra shielding from the fluorescent light.

Considerations Involving a Barometer Accurate to ±0.002 In. of Mercury

It is desirable to outline briefly some of the care and techniques that must be used to obtain an absolute accuracy of ±0.002 in. of mercury.

Temperature plays an extremely important role and must be controlled to at least 0.05°C. One way is to control the temperature of the air in a specific area which is located in a temperature-controlled room which, in turn, is located within a still larger temperature-controlled room. The barometer must be shielded from all heat-radiating sources such as lights and human bodies.

The barometer must be a U tube with the diameter precision bored to an accuracy of ±0.0002 in. This is necessary because of the optical considerations involved with determining the height of the mercury within the tube. In determining the height of the mercury column, a cathometer should be used in conjunction with a scale which has been engraved to an accuracy of ±0.0001 in. Corrections must be made for the shape of the meniscus.

The Bureau of Standards has stated that where an accuracy of better than 0.002 in. of mercury is expected, the installation will be too elaborate to be portable. In this case, they recommend that the scale and thermometer be calibrated at the National Bureau of Standards and any further evaluation be done at the point of use.

Conclusions

It is intended that this paper should instill a more complete appreciation for the problems associated with precise pressure measurements. The cost of providing pressure instrumentation for an ADC accurate to 0.25 per cent will be large. As these costs will be reflected to the customer, the customer should carefully evaluate ADC accuracy requirements in terms of aircraft performance.

The present state of the art of pressure measurement, typified by cistern barometers, is only partially satisfactory for a 0.25 per cent ADC. Satisfactory instrumentation may well consist of U tube barometers used in an area where the temperature is controlled very accurately.

It is felt necessary that industry develop new techniques and special equipment in the area of precise pressure measurement. With these, the cost of precise pressure measurement in terms of both time and money may be substantially lowered.

References

[1] Brombacher, W. G., *Some Problems in the Precise Measurement of Pressure*, National Bureau of Standards, Instruments, Vol. 22, April, 1949.

[2] Wichers, E., *Pure Mercury*, Chem. and Engrg. News, Vol. 20, pp. 1111–1112, September 10, 1942.

[3] *American Chemical Society Analytical Reagents*, Mack Printing Co., p. 77, March, 1941.

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Spin Characteristics for the T-37 (Continued from page 41)

necessary due to its primary mission function of training inexperienced pilots. Results were gratifying in that satisfactory recoveries were realized for a number of unusual conditions such as:

(1) Spinning into a dead engine with the other at 75 per cent r.p.m.

(2) 90 per cent r.p.m. on both engines.

(3) Normal recovery from a 5-turn spin after the elevator has been eased forward to neutral during the first turn (ailerons neutral, with or against the spin; any fuel load).

(4) Slow application of recovery controls.

(5) Elevator-alone recoveries with rudder free and rudder-alone recoveries with elevator free.

In addition, further work has been done on the fuel system which has materially reduced the possible fuel unbalance for even unusual operations conditions. This serves to assure at all times the excellent spin characteristics that have been demonstrated.

References

[1] Kerr, T. H., *The Spinning of Modern Aircraft*, Aircraft Eng., Vol. 26, No. 309, pp. 370–377, November, 1954.

[2] Clarkson, Mark H., *Autoration of Fuselages*, Aeronautical Engineering Review, Vol. 17, No. 2, pp. 33–36, February, 1958.

REPORT OF TECHNICAL SESSIONS
—26th Annual Meeting, IAS

New York City, January 27–30, 1958

By Allan Bernhardt

The REVIEW *is indebted to those Session Chairmen whose informal notes have made possible this condensed account of the 1958 Annual Meeting, held January 27–30, in New York City. It is intended to help readers who were unable to attend the meeting to decide whether to delve further into technical areas indicated by session titles, which appear alphabetically. For preprints still available, see page 128, March* REVIEW. *Some 1958 Annual Meeting papers have been published in the* REVIEW. *Others will appear in future issues or in the* JOURNAL OF THE AERONAUTICAL SCIENCES.

AERODYNAMICS: SEYMOUR M. BOGDONOFF, CHAIRMAN—This session heard papers on optimum thin lifting surfaces at supersonic speeds; on hydrodynamic stability of curved, laminar, compressible flows; and on magnetohydrodynamics. Some felt that the discussions indicated strongly the keen interest of the aerodynamicist in problems associated with high-speed ballistic missiles as differentiated from general airplane aerodynamics. Papers presented added much to the mass of information, mostly classified, which has been gathered by persons working directly on ballistic missiles.

AEROELASTICITY I: R. L. BISPLINGHOFF, CHAIRMAN—Concerned with questions of static aeroelasticity and dynamic response, this session presented an interesting array of discussions. The audience was shown how experiment and theory can be used systematically to predict aerodynamic derivatives of elastic airplanes. Two papers gave those present the opportunity to compare theories on the response of elastic airplanes to gusts with good experiments. A fourth paper, indicative of the type of problem facing aeroelastic and dynamics engineers, dealt with the interaction between elastic forces and combustion forces. A gun support structure was shown to alter the load and exit velocity of an ejected store.

AEROELASTICITY II: A. H. FLAX, CHAIRMAN—A description of a method for calculating stability and flutter derivatives on bodies which is based on linear perturbation around a mean flow as described by the full nonlinear potential flow equation began this session. Another paper was concerned with wing flutter at high Mach Numbers and involved the application of several simplified nonlinear theories. Also considered was calculation of stresses and vibration frequencies for curved beams and curved prismatic shells and the effect of time in varying parameters, such as density or velocity, on experimentally determined flutter boundaries.

Arthur E. Raymond *(left)*, winner of the 1957 Daniel Guggenheim Medal, looks on as Mundy I. Peale, IAS 1957 President *(right)*, prepares to present a certificate of Honorary Fellowship to Bo K. O. Lundberg, Director, Aeronautical Research Institute of Sweden. Mr. Raymond is Vice-President, Engineering, Douglas Aircraft Company, Inc.

AIR TRAFFIC CONTROL: DAVID D. THOMAS, CHAIRMAN—The current explosive growth of air traffic was defined and some of the available tools and present procedures were outlined in this session. Interest shown by the audience reflected that United States commerce and defense both are thoroughly dependent on the ability of the air traffic control system to permit aircraft to move safely and swiftly.

DESIGN AERODYNAMICS: C. E. PAPPAS, CHAIRMAN—Two papers of this session dealt with

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The author is Associate Editor of the *Review*.

minimization of the wave drag by modification or addition of a body over a subinterval of a given overall airplane configuration. Numerical solutions were presented by both. Successful firings of complete aircraft models in the aeroballistics range were recorded in the third paper, with comparisons between results obtained in the aerodynamics range and various high-speed tunnels. The fourth paper in this session, by Mark H. Clarkson, was published in full in the February REVIEW (pp. 33–36).

EARLY WARNING FOR AIR DEFENSE: L. V. BERKNER, CHAIRMAN—Radar early warning as a vital protection device for the United States was outlined in clear fashion by the initial paper in this session. The role of the DEW Line, operational aspects of the SAGE System, and a comparison between the problems of early warning in NATO Europe and in North America filled out the session.

EARTH SATELLITES: JOSEPH KAPLAN, CHAIRMAN—Cameras being used to determine orbital position of a satellite to within 30 ft., the liquid oxygen-hydrocarbon rocket engine designed to produce 27,000 lbs. thrust for about 140 sec. in the first stage of Vanguard, the Vanguard guidance system, and considerations paramount in the instrumentation of a small satellite were described in this session.

EDUCATION: VINCENT S. HANEMAN, JR., CHAIRMAN—Discussions in this session raised several points: (a) that a severe, if not critical, bottleneck in engineering education is the shortage of engineering teachers in colleges and that, while scholarship and student loans are going unused, aid to teachers in the form of both financial assistance and increased prestige is required to entice the young, qualified, aggressive, potential engineer into a teaching career; (b) that surface knowledge of the various subject matters is not sufficient—a broad background of much depth is required to make the student of today the leader of tomorrow; (c) that in order to design and construct creative "tigers" in the engineering world a method of instilling a degree of mental dissatisfaction must be found to ensure continued desire for learning and knowledge throughout the life span of the recipients of our education efforts.

ENGINEERING MANAGEMENT: JOEL JACOBSON, CHAIRMAN—This panel discussion on Long-Range Planning developed the following thoughts: A long-range plan would extend the consideration of company activities to include change in the character of the business in order to attain a desired goal which—be it maximum profit, maximum stability, maximum size, etc.—is more important than the long-range plan itself. It is essential only that the plan provide for the channeling of company activities to attain the desired goal. It must therefore be constantly reviewed and reoriented. Planned activities must be suitably timed and must be based on a thorough knowledge of the changing economic, social, and political conditions.

FLIGHT SAFETY: JEROME LEDERER, CHAIRMAN—Some of the most significant problems facing the civil aviation industry were discussed at this session. They included regulatory measures to achieve safety in jet operations, the problems of preventing mid-air collisions, the questions that airline management should ask itself in planning for the operation of jets, and means to improve survival in the event of accident.

GRAVITY: CHARLES TILGNER, CHAIRMAN—This session likened the state of relativity theory today to the state which would exist in hydrodynamics if only the propagation of a sound wave had been deduced from the theory. While theoreticians are trying to deduce all that is contained in the high nonlinear equations of the general theory of relativity, the experimentalists are probing the far reaches of the universe with optical and radio telescopes, cataloguing new nuclear particles, and creating miniature galaxies with plasma guns. Antigravity was held beyond the scope of present research, which still is trying to understand gravitational theory.

HYPERSONIC AERODYNAMICS: W. R. SEARS, CHAIRMAN—It became clear during this session that the classical blunt-body problem of hypersonics—

A major pause during the busy technical sessions was the Honors Night Dinner and reception at which Mundy I. Peale *(left)* presented a certificate of Honorary Fellowship to William Littlewood. Mr. Peale was IAS 1957 President and is President, Republic Aviation Corporation. Mr. Littlewood is Vice-President, Equipment Research, American Airlines, Inc.

the problem of calculating the shape of a detached bow shock wave in front of a blunt nose and the pressure distribution on the nose—finally has been solved for practical purposes. Successful techniques involve assuming the shock shape and calculating the flow pattern and nose shape that correspond to it. Remaining are the questions of chemical dissociation and recombination of air under the high-temperature conditions of hypersonic noses, though recent research findings have relieved some of their urgency.

INSTRUMENTS FOR HIGH-SPEED AIRCRAFT: REAR ADM. LUIS DE FLOREZ, CHAIRMAN—This session considered the USAF advanced instrument development program and the Army-Navy instrumentation program and disclosed a pilot's opinion of instruments to be required in the aircraft of the future. Efforts which have been made and are being continued by the military services were described.

METEOROLOGY: ROBERT D. FLETCHER, CHAIRMAN—Increased use of the balloon, manned and unmanned, for use both as a research and an operational tool for meteorology and geophysics in general, was indicated during this session. Papers outlined its recent accomplishments. The Chairman referred to the balloon as an "invaluable meteorological observatory, with its capability of measuring high level winds, temperatures, and densities; of photographing cloud systems from above; of securing atmospheric-radiation data, magnetic-force, and cosmic-ray information."

MISSILE GUIDANCE: R. E. GIBSON, CHAIRMAN—Papers brought out the complexity and sophistication of problems solved in this field of automatic control. Debated were the external and internal sources of intelligence, communication links and receivers available for guidance toward a variety of targets; an analysis of factors entering into the selection and use of intelligence, when it is desired to design missiles giving the highest performance under realistic conditions of signal, noise, and dynamic response; the design philosophy and development of a fully automatic system for providing an antiaircraft missile with all the information for accurate guidance; and problems arising from the boundary conditions that must be met if a satellite is to be guided into orbit to yield the maximum amount of scientific data.

MISSILES AND MISSILE PROPULSION: WILLSON H. HUNTER, CHAIRMAN—This session consisted of addresses by representatives of the Air Force, Navy, and Army. The remarks of this group are not available in the usual preprint form, and no abstracts were provided prior to their appearance.

MISSILE STRUCTURES: ERIC REISSNER, CHAIRMAN—Included in this session were two papers on vibrations of cylindrical and conical shells, one paper on optimum keyway design by thin shell theory, and one paper on general methods of semimonocoque analysis utilizing high-speed computing devices.

PROPULSION AERODYNAMICS: FRANK E. MARBLE, CHAIRMAN—This session included papers on a theory of wing-propulsion combinations in slow flight, the transonic flow field of an axial compressor blade row, supersonic airfoil performance with small heat addition, and the jet-flapped wing in two- and three-dimensional flow. The latter was a survey of theoretical investigations and comprised the more important results of four reports prepared during 1957 at Lockheed's Marietta, Ga., installation.

SPACE MEDICINE: MAJOR GEN. OTIS O. BENSON, JR., USAF, CHAIRMAN—The first paper in this session, by Major Charles A. Berry, USAF (MC), was published in full in the March REVIEW (pp. 35–38, 60). Others dealt with supersonic and hypersonic human flight, the biodynamics in human flight, cybernetics in human flight, and future prospects in human flight. The final paper, by Dr. Hubertus Strughold, may be found in this issue of the REVIEW (pp. 30–32).

SPACE PROPULSION: KRAFFT A. EHRICKE, CHAIRMAN—The general outline of a booster propulsion system for a space vehicle was presented, based on the current state of the art, in the first paper of this session. It was concluded that no major breakthroughs are required to achieve such a system. The second paper, by Robert Dillaway, is published in full in this issue of the REVIEW (pp. 42–49). The third and final paper of the session discussed an auxiliary power supply for space vehicles.

STRUCTURES: J. M. FRANKLAND, CHAIRMAN—The initial paper of this session pointed out that effects of sectional distortion on the strength and stiffness of curved stiffeners can be large. Supporting experimental data and design charts were presented. The second dealt with creep tests of large bolted joints of aluminum alloy. Satisfactory predictions of joint life could be made on the basis of material tests. No size effect was apparent. Both remaining papers were concerned with fatigue. One questioned whether safety in fatigue could best be achieved by use of lower-strength material and indicated that the use of specially designed details would permit a lighter structure in the stronger material. The other described fatigue tests of a C-130A fuselage in a hydraulic tank and discussed various failures encountered.

STRUCTURES—HIGH-TEMPERATURE EFFECTS: BRUNO A. BOLEY, CHAIRMAN—The five papers of this session covered the whole field of high-temperature structures with the exception of the materials properties phase. The first dealt with design and weight considerations, the next two with the heat

conduction problem, and the last two with some aspects of structural analysis proper at elevated temperatures. The first paper considered in some detail actual operating conditions and represented a needed first step in the field. The second and third papers of the session considered calculations of temperature distribution, respectively, numerically and analytically, indicating the high concern which structural engineers must now have for the heat conduction process itself. The fourth paper presented a new theory of creep buckling which explains the experimentally observed behavior of columns subjected to a constant axial load and a high-temperature ambient. The last paper presented several cases of heated and loaded rectangular sandwich plates and gave some results in short form for ready practical use.

ROTARY-WING AIRCRAFT DESIGN: ROBERT WAGNER, CHAIRMAN—Considerable interest was in evidence during the discussion following the two papers on ducted fans. There was general agreement that additional testing is needed before full understanding of the behavior of ducted fans is reached, particularly in the region of yawed flight. In the discussion following the paper on rotor blade weights, digital computation was recommended as a means of more exactly defining blade parameters and blade weights. Certain opposition to this technique, as being necessary or even desirable for parametric comparisons, was expressed. In blade deicing discussions, some concern was centered about the fate of ice shed from blades—i.e., whether it contacted other portions of the machine such as tail rotor, etc. It was pointed out that, with the shedding of ice 1/32 to 1/16 in., any damage caused would not be severe.

ROTARY-WING AIRCRAFT DYNAMICS: ROBERT G. LOEWY, CHAIRMAN—Papers in this session gave an analysis of the vertical flight dynamic characteristics of the lifting rotor with floating hub and offset coning hinges; described an application of the direct analog computer method to the analysis of helicopter rotors in vertical flight; and investigated (a) the handling qualities of a single-lifting rotor helicopter in hovering, low speed, and cruising flight, (b) the pitch-lag instability of helicopter rotors, and (c) pitch-lag instability as encountered during tests of model rotor.

VTOL-STOL AIRCRAFT: CAPT. SYDNEY S. SHERBY, USN, CHAIRMAN—This session concerned itself with two papers on research, a third looking into the future of VTOL supersonic transports, a fourth discussing the thinking of the Navy in applying the capabilities of VTOL-STOL aircraft, and a fifth dealing with the Army VTOL test bed program.

Sherman M. Fairchild Publication Fund Papers

No.		Member Price	Non-member Price
FF-19	Combustion—An Aeronautical Science—H. W. Emmons, 1958 Minta Martin Aero. Lecture	$0.75	$1.25
FF-18	On the Main Spray Generated by Planing Surfaces—Daniel Savitsky and John P. Breslin.	0.75	1.25
FF-17	Atomic Reactors (a Symposium).	1.25	1.75
FF-16	Inertial Guidance—W. Wrigley, R. B. Woodbury, and J. Hovorka (revised version of Prep. No. 698).	0.75	1.25
FF-15	Some Concepts and Problem Areas in Aircraft Flutter—I. E. Garrick, The 1957 Minta Martin Aeronautical Lecture.	0.50	1.00
FF-14	Engineering Management Philosophies (a Symposium).	0.50	1.00
FF-12	Transonic Testing Techniques (a Symposium).	1.85	2.50
FF-11	Wetted Area and Center of Pressure of Planing Surfaces at Very Low Speed Coefficients—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
FF-10	Improved Solutions of the Faulkner and Skan Boundary-Layer Equation—A. M. O. Smith.	0.75	1.25
FF-9	A Hydrodynamic Study of the Chines-Dry Planing Body—Experimental Towing Tank, Stevens Instit. of Tech.	1.20	1.60
FF-7	Natural Flight and Related Aeronautics—James L. G. Fitz Patrick.	2.65	3.50
FF-4	Finite Deflections of Curved Sandwich Plates and Sandwich Cylinders—F. K. Teichmann and Chi-Teh Wang.	0.50	0.85
FF-3	The Penetration of a Fluid Surface by a Wedge—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
FF-2	A Study of the Flow, Pressures, and Loads Pertaining to Prismatic Vee-Planing Surfaces — Experimental Towing Tank, Stevens Instit. of Tech.	1.20	1.60
AHS-1	Helicopter Flight Research at NACA, Langley—Jack P. Reeder.	0.35	0.75
286	Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours—Charles E. Mack, Jr., and Ignace I. Kolodner.	0.75	1.25
244	Wetted Area and Center of Pressure of Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
229	Wave Profile of a Vee-Planing Surface, Including Test Data on a 30° Deadrise Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
170	Wave Contours in the Wake of a 10° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Institute of Technology.	0.75	1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface—Experimental Towing Tank, Stevens Institute of Technology.	0.75	1.00
166	An Analysis of the Fluid Flow in the Spray Root and Wake Regions of Flat Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
165	Theory and Practice of Sandwich Construction in Aircraft (a Symposium).	1.85	2.50
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman.	0.75	1.00
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	0.35	0.50
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Mack, Jr.	1.85	2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	0.60	0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	2.65	3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	0.75	1.00

Papers should be ordered by number from: **Special Publications Dept., IAS, Inc., 2 East 64th St., N.Y. 21, N.Y.**

XUM

A CONCEPT OF SCIENCE

Five years ago, The Martin Company conceived a unique undertaking in the field of pure science which grew out of a belief that our own and our country's resources in creative scientific research must be greatly enlarged and cultivated.

We believed that the country—and the Company—that concentrates on short-range material achievements, without a deep concern for the creative source of tomorrow's even greater achievements, will have no tomorrow.

It is now three years since that belief motivated management's action with the foundation of a program in pure research. Known as the Research Institute of Advanced Study, RIAS is now a substantial organization staffed by scientists who are working in many fields, including theoretical physics, biochemistry, metallurgy and mathematics, without short-range applied research requirements.

Today, the increasing appeals to industry and the nation for accelerated activities in basic research give the RIAS story a special significance. For creative research in pure science is the true life source of our technological security—the "seed bed" from which our national strength shall continue to grow.

MARTIN

BALTIMORE·DENVER·ORLANDO

IAS News (Continued from page 18)

Equipment Section. . . . Radio Division has announced the appointment of Robert L. Adams as Assistant Manager, Government Products. . . . Friez Instrument Division has announced the appointment of Murray Kanes to the post of Director, Engineering. . . . Pacific Division reports E. Wayne Copeland has been appointed Telemetering Sales Manager.

• **Boeing Airplane Company** has established a new organization called Boeing Scientific Research Laboratories "to develop new fundamental knowledge at the frontiers of science." George S. Schairer, Director of Research, will serve as Acting Director pending appointment of a scientific director. C. B. Gracey has been appointed Vice-President, Operations; George C. Martin succeeds to Mr. Gracey's former post, General Manager, Seattle Division, and H. W. Withington has been named Division Chief Engineer. . . . The firm also announced it is working on two new missile projects—an advanced Bomarc and an antiballistic missile system. . . . Transport Division announced details of the 720 intermediate-range airliner: powered by a new version of the Pratt & Whitney J-57—the JT3C, top speed, 600 m.p.h.; gross payload of 33,000 lbs.; 130 passengers (tourist class); maximum range, 2,600 miles; same external dimensions as the 707.

• **Cornell Aeronautical Laboratory, Inc.,** has announced the addition of Roger W. Walker to its staff as Assistant General Manager. The Laboratory also announced five technical and one administrative appointment to its new combat surveillance group in Washington, D.C.: Herbert Nye, Assistant Head, Systems Requirements Department—Director of the group; Walter Brewer, Assistant Head, Systems Synthesis and Evaluation Group; Mark Foster, Head, Technical Characteristics Group; and Arthur Whiting, Head, Systems Requirements Group. John Egly has been named Administrative Assistant to Dr. Nye.

• **Edo Corporation** reports four international airlines have ordered Edo Airborne Loran as original equipment for their coming jet and turboprop fleets. The equipment consists of a remotely installed receiver unit occupying a 3/4 ATR rack, a compact pilot-operated command control installable in the cockpit, and a 3-in. scope.

• **Elastic Stop Nut Corporation of America** has announced a new line of self-locking, floating anchor nuts with a deep counterbore, designed to speed production and reduce weight of airframe and aircraft components where members of varying thicknesses must be joined.

• **Fairchild Camera and Instrument Corporation** has announced integration of its Reconaissance Systems and Electronics divisions into a new Defense Products Division. Charles J. O'Donnell has been named General Manager of the new division; Raul H. Frye is Assistant GM in charge of marketing and sales. R. G. Hennessey has been promoted to General Manager of the firm's Industrial Camera Division.

XUM

• **Fairchild Engine and Airplane Corporation** reports that its new guided missile Bull Goose has been successfully fired many times by the Air Force. An air-breathing vehicle, it is said to serve a variety of mission needs for SAC. The firm's Aircraft Division has the prime contract for the missile; power plant is being produced by the Engine Division and the guidance system by the Guided Missiles Division.

• **The Firestone Tire & Rubber Company** has announced the two new high-speed aircraft tires called Sky Champions for 200-m.p.h. take-off and landings. The firm says they will be original equipment on the Boeing 707.

• **The Garrett Corporation . . .** AiResearch Aviation Service Division has named Harold Richardson Assistant Manager. E. A. Bellande, a Vice-President of the company and Vice-Chairman of the Board, has been named to head Foreign Operations and Support Services.

• **General Dynamics Corporation . . .** Canadair Limited (Subsidiary) has announced that a turboprop version of the two-engine Convair Liner will be built for the RCAF and for airlines in a commercial configuration. Canadair will take over from Convair (San Diego) complete tooling and will set up production at Montreal. The new aircraft will be called the Canadair Cosmopolitan and will be powered by British Napier Eland-6 turboprop engines. Statistics: Gross weight, 53,200 lbs.; cruise speed, 326 m.p.h.; payload capacity, 44 to 60 passengers or 10,000 to 15,000 lbs.; maximum range, 1,700 miles. . . . The Electric Boat Division and General Atomic Division are working jointly on a prototype gas-cooled reactor, closed-cycle gas-turbine plant for merchant ship propulsion for the AEC and Maritime Administration, the firm announced. . . . Convair (Fort Worth) has announced that the B-58 is being equipped with a General Electric Vulcan tail gun. . . . Stromberg-Carlson Division has announced the appointment of James F. Conolly, Jr., as Administrator of its electronics division.

• **General Electric Company . . .** Aircraft Gas Turbine Division has announced the extension of a technical interchange agreement with DeHavilland Engine Company of Great Britain which will include production overseas of the T58 small turboshaft engine. Neil E. Firestone has been appointed General Manager of the division's Production Engine Department.

• **General Precision Equipment Corporation** has announced the appointment of Herbert W. Ziebolz as Coordinator of Industrial Systems and Assistant to the Vice-President, Engineering. . . . Link Aviation, Inc., has announced the election of David D. Mason as President of the firm. . . . Kearfott Company, Inc., has organized an Astronautics Laboratory within its Navigation Projects Department.

• **G. M. Giannini & Co., Inc.,** has announced the election of Donald H. Putnam as President of the firm. Robert Hodges has been named Manager, Airborne Systems Division.

• **The B. F. Goodrich Aviation Products,** a Division of The B. F. Goodrich Company, has named Bernard P. Rothermel Manager of Accounting at the firm's new rocket motor development plant in Rialto, Calif.

• **Johns-Manville Sales Corporation . . .** Industrial Insulations Division has announced the development of a new insulation material for missiles and rockets, the "Min-K," said to possess lower thermal conductivity than any other known insulating material. The firm says it would use one-third less space when applied to a missile, thus increasing fuel capacity.

• **Kelsey-Hayes Company . . .** Utica Metals Division reports that F. N. Darmara, General Manager, has been named to the NACA subcommittee on powerplant materials.

• **Lear, Incorporated . . .** Grand Rapids Division has reorganized its Contracts Division to include a Marketing Department under direction of R. N. Nielsen, former Manager, Missile Product Sales.

• **Liberty Aircraft Division, H & B American Machine Co., Inc.,** is the new name for what formerly was Liberty Aircraft Products Corp. H & B bought the Farmingdale, L.I., firm on January 2.

• **Lockheed Aircraft Corporation,** Missile Systems Division is building a 15,000-m.p.h. wind tunnel with a temperature extreme of 6,000 deg. at the Palo Alto research and development laboratories. Louis N. Ridenour, the division's head of research, has been appointed to the Air Force's Scientific Advisory Board. . . .

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Lamb Electric ***fractional*** horsepower motors, like the small horses of the famed western-pioneer-day Pony Express, are developed for *stamina.*

Their dependability, and efficiency (optimum weight-size-horsepower ratio) are qualities that result from proper design and careful manufacture by personnel with many years of experience in the small motor field.

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Typical of OEM Variac users is Consolidated Electrodynamics Corporation of Rochester, New York. Their line of high-vacuum pumps, stills, and metallizing equipment depends upon Variacs to provide long, reliable service for controlling laboratory and production processes.

The Evapor-ion Pump is a vacuum pump with no outlet. Titanium wire is fed into the center of the pump and is vaporized electrically. Upon striking the cooled pump wall, this vapor condenses into a thin layer. Molecules of active gases wandering into the pump strike this layer and are held as compounds by the titanium. Those gas molecules that are inert are ionized by electrons radiated from a heater filament — an accelerator grid then drives these ions into the titanium layer, where they are buried by subsequent condensation. This constant removal of air molecules by evaporation and ionization produces a pressure in the range from 10^{-4} to 10^{-9} Hg. Three Variacs are used to control titanium wire-feed rate, heater and accelerator-grid potentials.

Variacs are used as heat controls on CEC's Centrifugal Molecular Stills. These stills are capable of distilling any non-corrosive, heat-sensitive material having a molecular weight between 200 and 1200 that can be liquefied without molecular change. The model shown has sufficient capacity for pilot-plant distillation operations.

Variac continuously-adjustable autotransformers provide OEM users with high-efficiency voltage controls for a-c applications . . . All Variacs have Duratrak contact surfaces of plated silver alloy to eliminate oxidation problems that are present with bare copper brush tracks . . . Variacs can withstand initial surges up to ten times their normal ratings . . . Smooth continuous adjustment from 0 up to 117% of input is possible . . . Less than 50°C temperature rise under continuous operation . . . Can be easily designed into equipment for either panel, behind panel, wall, or table mounting . . . Available with current ratings from 2.4 to 50 amperes and may be ganged for additional capacity or polyphase operation . . . Available in ball bearing, or motor-driven forms . . . Variacs also available for 350- to 1200-cycle service . . . All Variacs are covered by a 2-Year-Warranty — additional life insurance for manufacturers who build equipment for long, trouble-free service.

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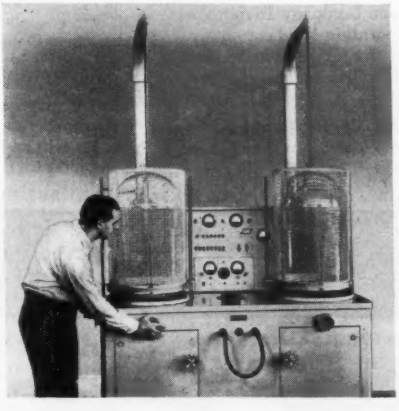

Variacs are used for controlling work heat, metal evaporation, and pump heat on CEC's High-Vacuum Metallizing Equipment. The model shown is designed for production-rate metallizing of small-sized plastic, metal, or glass pieces.

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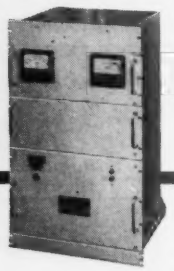

Write for Bulletin AC-58-A

CHRISTIE ELECTRIC CORP.
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Over a Quarter Century of Rectifier Manufacturing

Georgia Division reports that a Direct Analogy Electric Analog Computer is being installed in the plant's engineering electronic computer center.

• **Marquardt Aircraft Company** has designated Astro as the name for its Long-Range Planning & Research Division. It is a contraction of Air-Space Travel Research Organization.

• **Pan American World Airways, Inc.,** has announced that it will establish a jet overhaul base on 112 acres at Miami, Fla. The base will include maintenance shops and supply depots, international cargo area, a building for Latin American Division executive and general offices, five hangars, two nose docks, and 47 acres of paved ramp and taxi area.

• **Pesco Products Division, Borg-Warner Corporation,** has announced formation of a new Automatic Warehousing Branch to specialize in design and fabrication of automated systems.

• **The Ramo-Wooldridge Corporation** has named Irwin A. Binder Vice-President for Manufacturing.

• **Republic Aviation Corporation** reports the Alouette II rotojet helicopter has been certified for commercial operation in the United States. Republic is licensed to assemble and sell the helicopter here. Four Republic executives named to the NACA committees are Alexander Dartveli, Vice-President, Research and Development—aerodynamics; William J. O'Donnel, Chief Engineer, Aircraft and Missiles Development—internal flow; William I. Steiglitz, Design Safety Engineer—flight safety; and Albert Epstein, Chief Design Requirements Engineer—aircraft loads.

• **Ryan Aeronautical Company** has named Herbert E. Ryker Assistant to Executive Vice-President George C. Woodard.

• **Simmonds Accessories, Inc.,** has announced the availability of a fuel injection test stand designed for testing Simmonds fuel injection systems for gasoline engines. Data Sheet No. PD 3513-1 is available from the firm at Tarrytown, N.Y.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has been named prime contractor for development and production of electronic countermeasures for SAC B-52's.

• **Stanley Aviation Corporation** has developed a rapid response gamma radiation counter said to have a response rate on the order of 10 millisec. or better. The company also announced that James H. Klein has joined its staff as Chief Research Engineer. Dr. Klein will be engaged in expanding technical capabilities of Stanley and in extending and diversifying its activities to the missile and nuclear power fields.

• **Thompson Products, Inc.,** has taken Kolcast Industries, Inc., a wholly owned subsidiary, into the parent firm as "Kolcast Industries, a Division of Thompson Products, Inc."

• **United Air Lines, Inc.,** has announced the appointment of Alfred M. Salmon as resident representative for the firm at the Boeing Airplane Company Transport Division. Staff promotions recently announced are: (Chicago offices) Richard A. Young, Assistant to the Vice-President—Facilities and Property; George E. Marshino, Facilities Manager; Spence LeRoy, Property Manager; (San Francisco) E. J. Lupien, Facilities and Property Manager; Robert E. Worcester, Facilities Manager; and W. E. Ottenstein, Technical Staff Assistant—Facilities.

• **United Aircraft Corporation . . .** Hamilton Standard Division has announced the appointment of Paul Helweg as Assistant Sales Manager, Electronics Department. Charles H. Jackson has joined the department staff as Project Engineer, Advanced Design Group.

• **Vertol Aircraft Corporation's** Board of Directors has approved acquisition of Allied Research Associates, Inc., of Boston and has elected the firm's President, Lawrence Levy, a Vertol Director.

• **Vickers Incorporated . . .** J. Frank Forster has been appointed President of Vickers. He succeeds Kenneth R. Herman who was elected an Executive Vice-President of Sperry Rand Corporation, of which Vickers is a division. Walter L. Flinn has been promoted to the newly created position of Staff Director—Defense Activities. Fred A. Klemach has been appointed Senior Staff Engineer for missile applications.

• **Western Gear Corporation** reports that all San Francisco Bay Area operations of the firm will be concentrated at its Belmont Works. The company also announced that new buildings and enlargement of present structures is under way. The Industrial Products manufacturing division will be located at Belmont.

IAS SECTIONS

Atlanta Section

Movie Produced for Student Branches

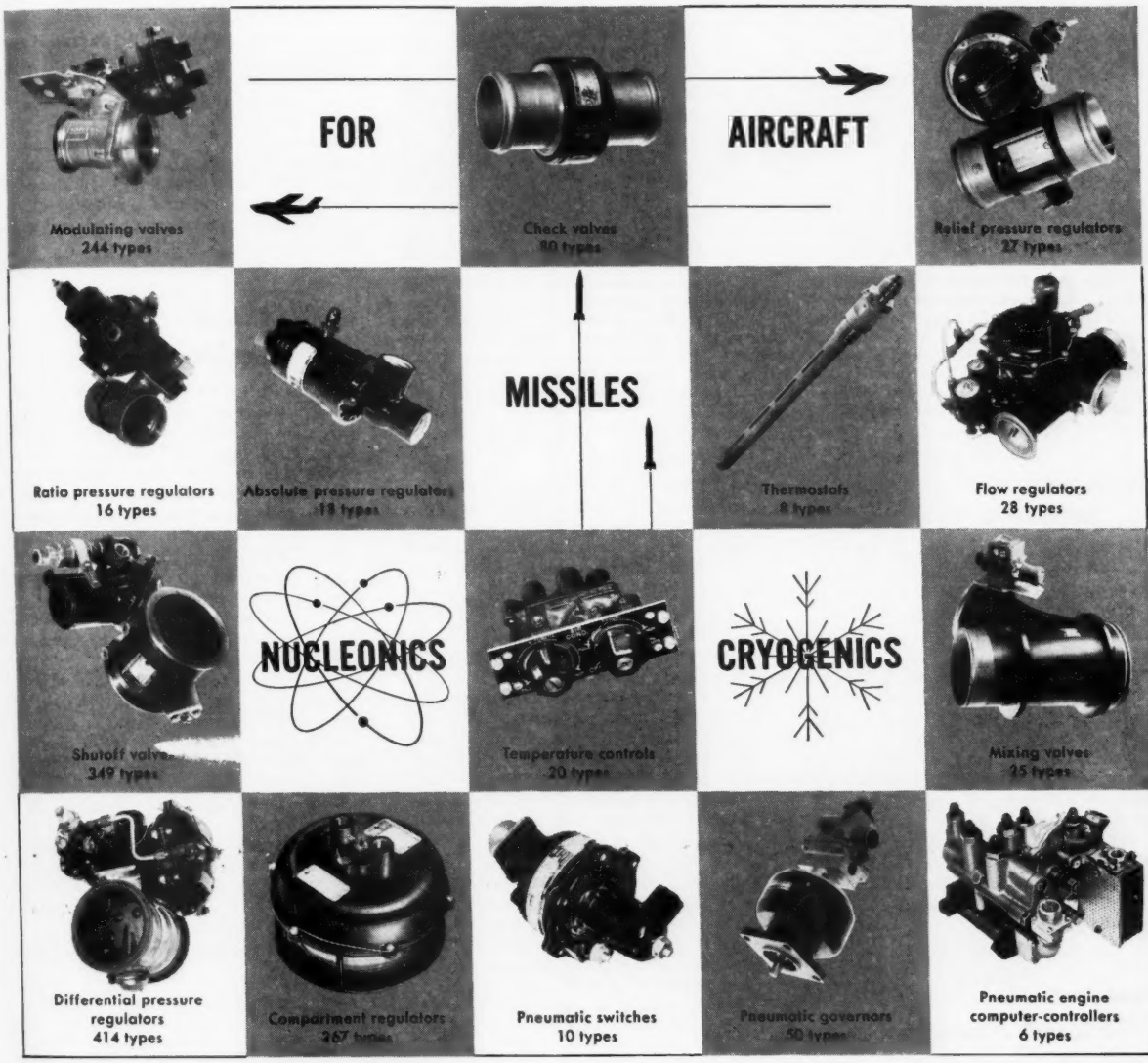
A new 20-min. sound film, *Advance and Be Recognized*, has been produced by Section members for the more than 4,000 Student Members of the IAS. The film will be available to them at an early date.

The movie describes the 1957 Southeastern Regional Student Conference as seen through the eyes of one student attending. It traces each phase of this representative conference, including field trip, presentation of student papers, and the prize award banquet.

Prints will be sent to all conference hosts for distribution to Student Branches in the area covered by each conference. Information on circulation of the film will be sent to Branch faculty advisers by conference hosts.

XUM

Pneumatic controls



AiResearch is the largest designer and manufacturer of pneumatic controls for the aircraft and associated industries. During the past 10 years more than 300,000 units have been produced and are in service.

Temperatures of the fluids (including gas and liquids) range from −400°F to +2000°F at pressures to +6000 psig. The units operate at any ambient pressure at ambient temperatures from −300°F to over +1000°F. Line diameters range from ⅛ inch to 15 inches.

This equipment is developed and tested in the finest pneumatic facilities in the world. Your inquiries are invited.

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More than 500 members and guests of the San Francisco Section heard H. Julian Allen, Chief, High Speed Research Division, Ames Aeronautical Laboratory, speak on "Hypersonic Flight and the Re-Entry Problem," the IAS Wright Brothers Lecture, given last December. Left to right at the guest table are: Smith J. DeFrance, Ames Director; James H. Doolittle, Vice-President, Shell Oil, and Chairman, NACA; Mr. Allen; Section Chairman Robert McIver, United Air Lines; Russell G. Robinson, Ames Assistant Director; Section Secretary Daniel Bershader, Lockheed Missile Systems and Stanford University; and Section Vice-Chairman Robert M. Crane of Ames.

Chicago Section

Seaplanes in Air Logistics

"The Case for Water-Based Air Logistics" was presented by Guy Mallery, The Martin Company, before 75 members and guests on December 11. Mr. Mallery is Advanced Design Department Project Engineer.

He said a modern large seaplane can be built to carry at jet speeds three light tanks or an entire infantry company fully equipped with vehicles and 3 days' supplies. They are not subject to the hazards of combat-zone land runways and have the advantage of greater dispersibility.

Mr. Mallery illustrated his talk with color films of the P6M SeaMaster and slides depicting the SeaMistress, an eight-engine jet seaplane weighing from 200 to 300 tons.

DICK SCHRAM, *Vice-Chairman*

Kansas City Section

McDonnell Aircraft Reviewed

Some 35 members and guests heard "An Engineering History of McDonnell Aircraft Products" related by Mike Weeks at the January 28 meeting. Mr. Weeks is Chief, Preliminary Design, at McDonnell.

His talk, illustrated with slides, included comments on performance and design objectives and actual accomplishments.

During the business portion of the meeting, members discussed a scholarship committee which would initiate a scholarship award supported by local industry and sponsored by the Section.

J. R. MACPHERSON, *Secretary*

Los Angeles Section

Crossfield, Flickinger Advocate Man in Missile

"Jet Noise" with associated theories and experimentation was discussed by Alan Powell at the January 28 specialist meeting. Dr. Powell reviewed the use of small-scale tests and the analysis techniques on the coupling between shock waves and acoustic pressure waves.

▶ More than 500 members and guests heard Brig. Gen. Donald D. Flickinger and Scott Crossfield speak on "Put the Man Back into the Missile" at the January 23 meeting.

General Flickinger said critical analysis had revealed a clear advantage in net mission effectivity for the manned space traversing vehicle. He said an improvement in system reliability, efficiency, and economy of from 60 to 70 per cent can be realized at a weight cost of only 5 to 10 per cent for the human crew.

Mr. Crossfield discussed the role of human factors in their relationship to cislunar flight in which humans are placed into vehicles in flight in the area between an earth orbit and moon orbit.

General Flickinger is Director, Human Factors, and Command Surgeon, ARDC. Mr. Crossfield is a key engineer in the North American Aviation X-15 research program.

Field trips during January included visits to Kaiser Steel on January 10 and Continental Can on January 16 and 17.

▶ On January 7 some 170 wind-tunnel specialists heard Raymond L. Chuan discuss "Modern Wind-Tunnel Techniques." Dr. Chuan covered the use of rarefied gas in high Mach Number tunnels and use of solidified nitrogen and magnetically controlled plasma heating.

▶ H. Julian Allen, Chief, High Speed Research Division, Ames Aeronautical Laboratory, discussed "Hypersonic Flight and the Re-Entry Problem" on December 20. This was a repeat of the December 17 IAS Wright Brothers Lecture.

Some 200 members and their families visited Kaiser Steel's Fontana plant on December 13. Blast furnaces, open hearth furnaces, rolling mills, and tinning mills were seen.

H. D. MORAN, *Secretary*

Philadelphia Section

Missiles vs. Aircraft

Some 200 members and guests of this Section and its SAE and ARS counterparts heard Rear Adm. John T. Hayward discuss "Manned Aircraft vs. Guided Missiles" on January 8. Admiral Hayward is Assistant Chief, Naval Research and Development.

His discussion anticipated the strategic and tactical role of guided missiles in naval warfare. The overall weapon requirements for the missile era will include many manned aircraft now in production and under development. The potential of missile-carrying submarines also was discussed, and slides were shown.

W. WELSH GODON, *Secretary*

San Antonio Section

New Officers Installed

A constitution for the Section, developed by the Chairman and Treasurer, was approved by members after minor amendments at the January 17 business meeting.

Members also approved a plan to present prizes in the name of the IAS at two science fairs scheduled in San Antonio. This will be handled by the Student Activities Committee.

The Chairman presented an outline program for 1958 activities that calls for one meeting each month. Earlier, members approved appointments to the Section's Advisory Board.

▶ New officers for 1958 installed at the December 17 meeting were Col. Leigh H. Hunt, USAF, Chairman; Cecil W. Barnes, Vice-Chairman; Major Robert A. Schneider, USAF, Treasurer; and Robert R. Perry, Secretary.

Major Gen. Charles J. Bondley, Jr., Director of Supply, HQ USAF, spoke extemporaneously on a single service and its advantages in present-day defense planning. General Bondley substituted for Lt. Gen. C. S. Irvine, the scheduled speaker who was unable to appear.

ROBERT R. PERRY, *Secretary*

St. Louis Section

Vanguard Reviewed

Donald J. Markarian discussed "Project Vanguard" before more than 1,000 members and guests of the Section, its AIEE counterpart, and sections of several other societies on January 15. Mr. Markarian is Vanguard Project Engineer, The Martin Company.

He reviewed plans for the earth satellite program and showed slides of dynamic mock-ups used in performing the physical tests on the launch vehicle prior to actual firing.

H. H. LUETJEN, *Recording Secretary*

Tullahoma Section

Nuclear Aircraft Tests

Robert A. Thompson discussed "Nuclear Aircraft" at the December meeting. His talk centered on the role of

(*Continued on page 114*)

XUM

A Word About Our Advertisers

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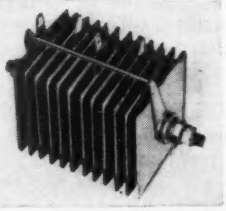

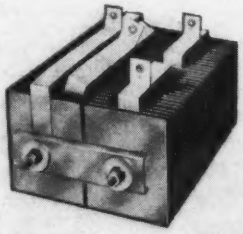

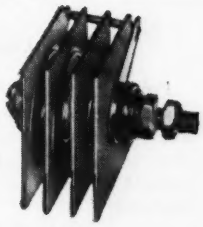

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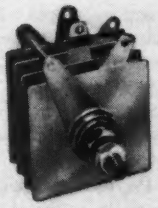

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INTER-OFFICE MEMORANDUM

To Advertising Department *Subject* Recruitment Advertising for Engineers

From Vice President - Engineering

As the result of expanding activity in recent months, we have come up with a few openings for good engineers. Specifically, we need designers in the following product groups:

Pneumatic accessories
Electric motors
Fuel systems controls (pumps and valves)
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The requirements are not pressing: our present team can still carry the increased load. We're proud of the boys we now have, and it's important that we find exactly the right people to add to the group. Therefore, before you rush into print with the usual sort of "recruitment" advertising, here are some thoughts to use in formulating your message:

1. We don't hire engineers by the carload, and we don't stockpile them in reserve until the right project happens to come along. Our people are busy...very busy; and they like to be busy. They follow through on their ideas from inception to development and qualification. They feel a real responsibility for the hardware that finally results from their work. Therefore, we need more idea men with initiative and drive who are not afraid to get their hands dirty.

2. Don't write a lot of guff about "security" and "bright future." The kind of men we want carry their security around with them. They have the self-assurance that comes from ability and experience. Chances are they've known about our company for several years and have followed our progress in the industry. If they answer our ads, it means they like us - and they think they can help us to grow.

3. The kind of man we want will join us because we treat our engineers in the same way we treat our other key people. We don't isolate them and we don't put them on pedestals. We expect results; we know how to look for results; and we reward amply when we find them.

One other point: the man who meets our requirements is probably too busy to write a long resume and application letter. Just tell him to call me personally, or to drop me a short note to let me know where I can contact him - to Hydro-Aire, Inc., 3000 Winona Avenue, Burbank, California. Phone: VIctoria 9-1331.

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Acoustics, Sound, & Noise

Sonic Bangs. G. H. Lee. *Handley-Page Bul.*, Winter, 1957, pp. 14–17. Explanation, in simple terms, of the fundamental principles involved and of the origin of sonic bangs. Includes compressibility effects, shock-wave shape, audible bangs, double bangs, and explosive effects.

Quick-Fix Recommendations for Reduction of Jet Engine Noise in Air Force Control Towers. R. J. Christman and L. R. Pinneo. *USAF RADC TR 57-189 [AD 131374]*, Dec., 1957. 15 pp. Presentation of several techniques for use by local AACS units.

Aerodynamics

Barriera Sonica e Barriera Termica. Carlo Ferrari. *Torino Polytech. Inst., Aero. Lab., Monograph 404*, 1956. 22 pp. In Italian. Determination of the sonic and thermal barriers and discussion of related problems.

On the Generalized Prandtl Relation. Rudi S. Ong. *J. Aero. Sci.*, Mar., 1958, pp. 209, 210. Analysis of a four-dimensional Euclidean space-time manifold.

Aerothermodynamics

Influence de l'Echauffement Cinétique sur la Réponse Vibratoire du Mode de Torsion d'une Voilure. E. Bonneau. *La Recherche Aéronautique*, Nov.-Dec., 1957, pp. 27–34. In French. Simplified quantitative study of the effect of kinetic heating on the vibratory response of the torsional mode of an airfoil.

La Cinética de la Transferencia del Calor por Convección y por Rozamiento sobre Superficies Especulares. Eugen Sanger. *Asoc. Argent. Interplan. Rev.*, July-Dec., 1957, pp. 31–41. In Spanish. Study of the kinetics of heat transfer by convection and boundary-layer friction in bodies at hypersonic velocities.

A Note on the Expressions for the Local Heat-Transfer Coefficient. Richard R. Gold. *J. Aero. Sci.*, Mar., 1958, pp. 208, 209. Calculations for the case of an isothermal flat plate at zero angle of attack.

Some Effects of Bluntness on Boundary-Layer Transition and Heat Transfer at Supersonic Speeds. Appendix A, B—**Dissipation of the Low Mach Number Layer.** Appendix C—**Mach Number Profiles Produced by Detached Shock Waves.** W. E. Moeckel. *U.S., NACA Rep. 1312*, 1957. 14 pp. 19 refs. Supt. of Doc., Wash., $0.20. Discussion of the stability and dissipation of blunt profiles, and description of a method for estimating the amount of blunting required to produce the maximum possible downstream movement of transition.

Ob Usloviiakh Primenimosti Zakonov N'iutona i Fur'e k Raschetu Soprotivleniia Treniia i Teploobmena na Poverkhnosti Obtekaemykh Potokom Tel. E. A. Sidorov. *Teploenergetika*, Dec., 1957, p. 73. In Russian. Analysis of the applicability of Newton and Fourier laws to the calculation of drag due to friction and heat-transfer over the surface of bodies in a gas flow.

On Turbulent Heat Transfer Through a Highly Cooled Partially Dissociated Boundary Layer. Ronald F. Probstein, Mac C. Adams, and Peter H. Rose. *Jet Propulsion*, Jan., 1958, pp. 56–58. USAF-sponsored presentation of some analytical results regarding the properties of a compressible turbulent boundary layer in thermodynamic equilibrium.

Heat Transfer to a General Three-Dimensional Stagnation Point. Eli Reshotko. *Jet Propulsion*, Jan., 1958, pp. 58–60. Presentation of equations for the compressible laminar boundary layer at the stagnation point of a body having unequal principal curvatures, including a simple heat-transfer representation for the case of a very cold wall, and estimates of the heat transfer at other temperatures.

Flows in Partly Dissociated Gases. Hans-Joachim Metzdorf. *J. Aero. Sci.*, Mar., 1958, pp. 200–201. Solution of equations for the case of an isolated plate with special boundary conditions, once with and then without the consideration of the influence of diffusion on the heat conductivity.

Boundary Layer

Turbulentnyi Pogranichnyi Sloi na Vrashchaiushchemsia Diske. L. A. Dorfman. *AN SSSR Otd. Tekh. Nauk Izv.*, July, 1957, pp. 138–142. In Russian. Investigation of the turbulent boundary layer on a rotating disk based on the velocity profile.

Influence de l'Onde de Choc au Bord d'Attaque sur le Comportement de la Couche Limite Laminaire aux Grandes Vitesses. Max Plan. *Fusées*, Dec., 1956, pp. 269–278. In French. Experimental investigation of the effect of leading-edge shock waves on the behavior of laminar boundary layers at high speeds.

Asupra Determinării Caracteristicilor Stratului Limită prin Utilizarea unor Profile Tip de Viteze şi Temperaturi. St. Săvulescu. *Stud. Cerc. Mec. Aplic.*, No. 2, 1957, pp. 341–356. 17 refs. In Rumanian, with summaries in Russian and French. Development of a method for determining boundary-layer characteristics by means of standard velocity and temperature profiles.

Control Surfaces

Flight Investigation of the Effectiveness of an Automatic Aileron Trim Control Device for Personal Airplanes. William H. Phillips, Helmut A. Kuehnel, and James B. Whitten. *U.S., NACA Rep. 1304*, 1957. 15 pp. Supt. of Doc., Wash., $0.25.

Profil cu Volet Fluid în Prezenţa unor Singularităţi Date. N. N. Patraulea. *Stud. Cerc. Mec. Aplic.*, No. 2, 1957, pp. 313–317. In Rumanian, with summaries in Russian and French. Generalization of the problem of a profile equipped with a jet flap, corresponding to the case of a known velocity field specified by certain known singularities.

Cercetări Experimentale Asupra Profilelor Aerodinamice Suflate. N. N. Patraulea, L. Dumitrescu, C. Popescu, D. Căpriţă, and H. Gab. *Stud. Cerc. Mec. Aplic.*, No. 2, 1957, pp. 319–340. 14 refs. In Rumanian, with summaries in Russian and French. Results of experimental investigations on blown aerodynamic profiles to obtain maximum lift. Test equipment and methods are also described.

Determinarea Efectului de Ejectile la Profile cu Volet Fluid (Jet-Flap). Lucian Dumitrescu. *Stud. Cerc. Mec. Aplic.*, No. 2, 1957, pp. 357–378. 12 refs. In Rumanian, with summaries in Russian and French. Determination of the effect of ejection for two profiles equipped with jet flaps.

Fluid Mechanics & Aerodynamic Theory

Asimptoticheskoe Reshenie Uravnenii Odnomernogo Neustanovivshegosia Dvizheniia Ideal'nogo Gaza s Tsilindricheskoi Simmetriei. G. M. Shefter. *AN SSSR Dokl.*, Oct. 1, 1957, pp. 572–575. In Russian. Derivation of an asymptotic solution of equations for one-dimensional unsteady motion of an ideal gas with a cylindrical symmetry.

Asimptoticheskoe Reshenie s Tremia Proizvol'nymi Funktsiiami Uravnenii Odnomernogo Neustanovivshegosia Dvizheniia Gaza. Iu. L. Iakimov. *AN SSSR Dokl.*, Oct. 21, 1957, pp. 937, 938. In Russian. Derivation of an asymptotic solution for the equations of one-dimensional unsteady gas motion, involving three arbitrary functions, and description of the method of solution.

A Test of the Uniqueness of Solutions for Problems of Nonsteady Flow Under Given Boundary Conditions. J. Altenhoff. *J. Aero. Sci.*, Mar., 1958, pp. 210–212.

Opredelenie Osesimmetrichnogo Potentsial'nogo Dvizheniia Neszhimaemoi Zhidkosti po Zadannym Znacheniiam Napravleniia ee Skorosti. G. N. Pykhteev. *Iaşi Politeh. Inst. Bul.*, Fasc. 3–4, 1956, pp. 35–38. In Russian, with summaries in English and Rumanian. Determination of the axially symmetric potential motion of an incompressible fluid from given values of the direction of its velocity.

Ob Odnom Klasse Ploskoparallel'nykh Ustanovivshikhsia Vikhrevykh Dvizhenii Gaza. Iu. S. Zav'ialov. *AN SSSR Dokl.*, Sept. 21, 1957, pp. 363, 364. In Russian. Study of a certain class of plane, steady, rotational gas flows.

Universelle Wandabstandsfunktionen bei Gleichgewichtsturbulenz. H. B. Helmbold. *Forschung Gebiete Ing., Ausg. A*, No. 6, 1957, pp. 210–213. 11 refs. In German. Survey of previously obtained experimental results leading to the establishment of certain conditions for turbulent flows in pipes, channels, and diffusers, as well as around plates, thus covering the equilibrium turbulence in flows with or without pressure gradient in flow direction.

Techenie Vazkogo Gaza v Zazore Mezhdu Dvumia Koaksial'nymi Tsilindrami. Ia. M. Kotliar. *AN SSSR Otd. Tekh. Nauk Izv.*, Oct., 1957, pp. 12–18. In Russian. Study of the spacial flow of a compressible viscous gas in the space between two coaxial circular cylinders.

Incompressible Two-Dimensional Stagnation-Point Flow of an Electrically Conducting Viscous Fluid in the Presence of a Magnetic Field. Joseph L. Neuringer and William McIlroy. *(IAS 26th Annual Meeting, New York, Jan. 27–30, 1958, Preprint 764.)* *J. Aero. Sci.*, Mar., 1958, pp. 194–198.

O Reshenii Tipa Dipolia v Zadachakh Nestatsionarnoi Fil'tratsii Gaza pri Politropicheskom Rezhime. G. I. Barenblatt and Ia. B. Zel'dovich. *Prikl. Mat. i Mekh.*, Sept.-Oct., 1957, pp. 718–720. In Russian. Derivation of a dipole-type solution for problems of nonstationary filtration of a gas in the case of polytropic regime.

O "Vtoroi" Forme Dvizheniia Ideal'noi Zhidkosti Okolo Obtekaemogo Tela (Issledovanie Otryvnykh Vikhrevykh Potokov). A. A. Nikol'skii. *AN SSSR Dokl.*, Sept. 11, 1957, pp. 193–196. In Russian. Investigation of the "second" form of motion of an ideal fluid past a solid—formation of discontinuous vortical flows.

K Voprosu o Mekhanizme Kavitatsii v Tsentrobezhnykh Nasosakh. V. F. Chebaevskii. *Teploenergetika*, Sept., 1957, pp. 12–16. In Russian. Presentation of results of a study of the cavitation mechanism in centrifugal pumps.

O Tochnom i Priblizhennom Resheniiakh Odnoi Ploskoi Zadachi Fil'tratsii pri Smeshannykh Granichnykh Usloviiakh. V. N. Nikolaevskii. *AN SSSR Otd. Tekh. Nauk Izv.*, Oct., 1957, pp. 102–105. In Russian. Derivation of exact and approximate solutions for a plane filtration problem in the case of mixed boundary conditions.

O Krizise Laminarnogo Techeniia Viazkoi Zhidkosti pri Estestvennoi Konvektsii. L. S. Eigenson. *Teploenergetika*, Dec., 1957, pp. 66–69. In Russian. Application of theoretical solutions obtained for four problems of laminar flow due to natural convection together with experimental data to determine critical values of *Re* for the natural convection.

Überschallströmungen von hoher Machzahl bei kleinen Strömungsgeschwindigkeiten. Carl Pfleiderer. *VDI Zeitschrift*, Oct. 21, 1957, pp. 1,535, 1,536. In German. Analysis of the operation of mixed-flow units such as water-jet pumps and pulsating pump units. By using suitable diffusers and induction nozzles high-speed flows can be produced with a low-velocity driving medium.

Vliianie Izlucheniia na Rasprostranenie Malykh Vozmushchenii v Viazkoi i Teploprovodnoi Zhidkosti (Gidrodinamicheskaia Teoriia). V. A. Prokof'ev. *AN SSSR Otd. Tekh. Nauk Izv.*, July, 1957, pp. 94–102. In Russian. Study of the influence of radiation on the propagation of small perturbations in a viscous heat-conducting liquid.

Calculation of Laminar Flow of Drop-Forming Liquids Through Tubes, with Inclusion of Non-isothermal Effects. E. A. Sidorov. *Sov. Phys.-Tech. Phys.*, Feb., 1957, pp. 292–296. Translation.

On the Electric Tank Method for Study of Centrifugal Machines. Syōgo Matsunaga. *J. Aero. Sci.*, Mar., 1958, pp. 202, 203. Development of an approximate method to study non-axisymmetric flows by an electric-tank method.

O Silovom Vozdeistvii "Vtoroi" Formy Gidrodinamicheskogo Dvizheniia na Ploskie Tela (Dinamika Ploskikh Otryvnykh Potokov). A. A. Nikol'skii. *AN SSSR Dokl.*, Sept. 21, 1957, pp. 365–368. In Russian. Investigation of the effect of force due to the "second" form of hydrodynamic motion on flat bodies—the dynamics of plane discontinuous flows.

O Telakh Naimen'shego Soprotivleniia pri Bol'shikh Sverkhzvukovykh Skorostiakh. A. L. Gonor and G. G. Chernyi. *AN SSSR Otd. Tekh. Nauk Izv.*, July, 1957, pp. 89–93. In Russian. Study of bodies of least drag at high supersonic velocities.

Approximate Solution for Slightly Yawed n-Power Bodies at Hypersonic Speeds. Robert W. Truitt. *J. Aero. Sci.*, Mar., 1958, pp. 206, 207.

A Special Case of Swirling Viscous Flow. Dennis G. Mabey. *J. Aero. Sci.*, Mar., 1958, pp. 212–214. Presentation of an exact solution for the equations of incompressible viscous flow for axisymmetric motion with swirl.

Explosive Induced Shock Waves. I—Plane Shock Waves. William E. Drummond. *J. Appl. Phys.*, Dec., 1957, pp. 1,437–1,441. 11 refs. Army-sponsored analysis of the explosive production of plane shock waves in solids, using the approximation that third and higher order shock strength terms can be neglected, and development of a procedure for shock-attenuation calculations. Application is made to the determination of the equation of state of burned explosive gases.

O Tochnykh Resheniiakh Linearizirovannoi Zadachi o Tochechnom Vzryve s Protivodavleniem. V. P. Korobeinikov and N. S. Mel'nikova. *AN SSSR Dokl.*, Sept. 11, 1957, pp. 189–192. In Russian. Derivation of exact solutions of the linearized problem of point explosion with counterpressure.

On Slender-Body Theory at Transonic Speeds. Keith C. Harder and E. B. Klunker. *U.S., NACA Rep. 1315*, 1957. 6 pp. 17 refs. Supt. of Doc., Wash., $0.10. Application of the basic ideas of slender-body approximation to the nonlinear transonic-flow equation for the velocity potential, in order to obtain some of the essential features of slender-body theory at transonic speeds.

Turbulent Flow in a Stably Stratified Atmosphere. A. A. Townsend. *J. Fluid Mech.*, Jan., 1958, pp. 361–372. Analysis of fluctuations of velocity and temperature which occur in a turbulent flow in a stably-stratified atmosphere far from restraining boundaries, in terms of equations for the turbulent intensity and for the mean square temperature fluctuation.

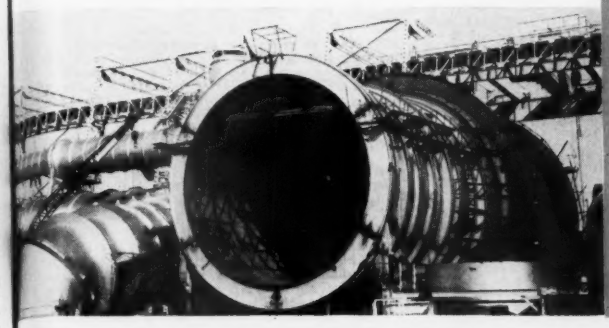
Internal Flow

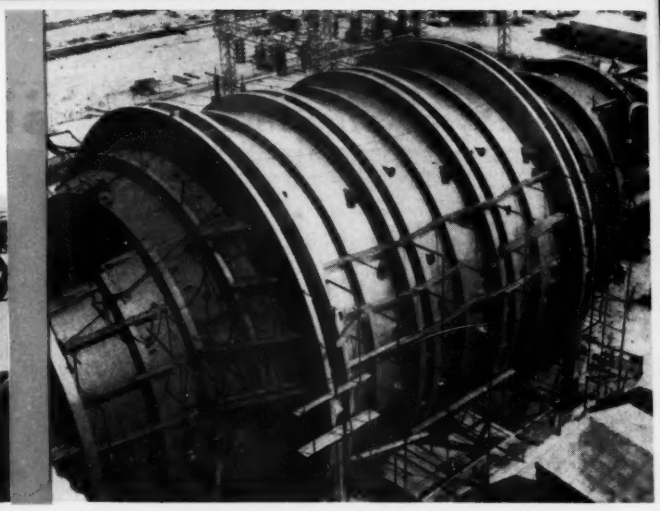
Asupra Mişcării Nepermanente a unui Fluid într-o Retea de Profile. I. L. Popescu. *Bul. Ştiint. Sect. Ştiint. Mat. Fiz.*, Jan.-Mar., 1957, pp. 121–137. In Rumanian, with summaries in Russian and French. Generalization of Sedov's theory for thin wings in nonstationary flow and application to the study of nonstationary motion of a perfect incompressible fluid flowing through a cascade of airfoils.

Die Konstruktion von Schaufelsternen mit rückwärts gekrümmter Beschaufelung. J. Gruber. *Periodica Polytech.*, No. 1, 1957, pp. 43–49.

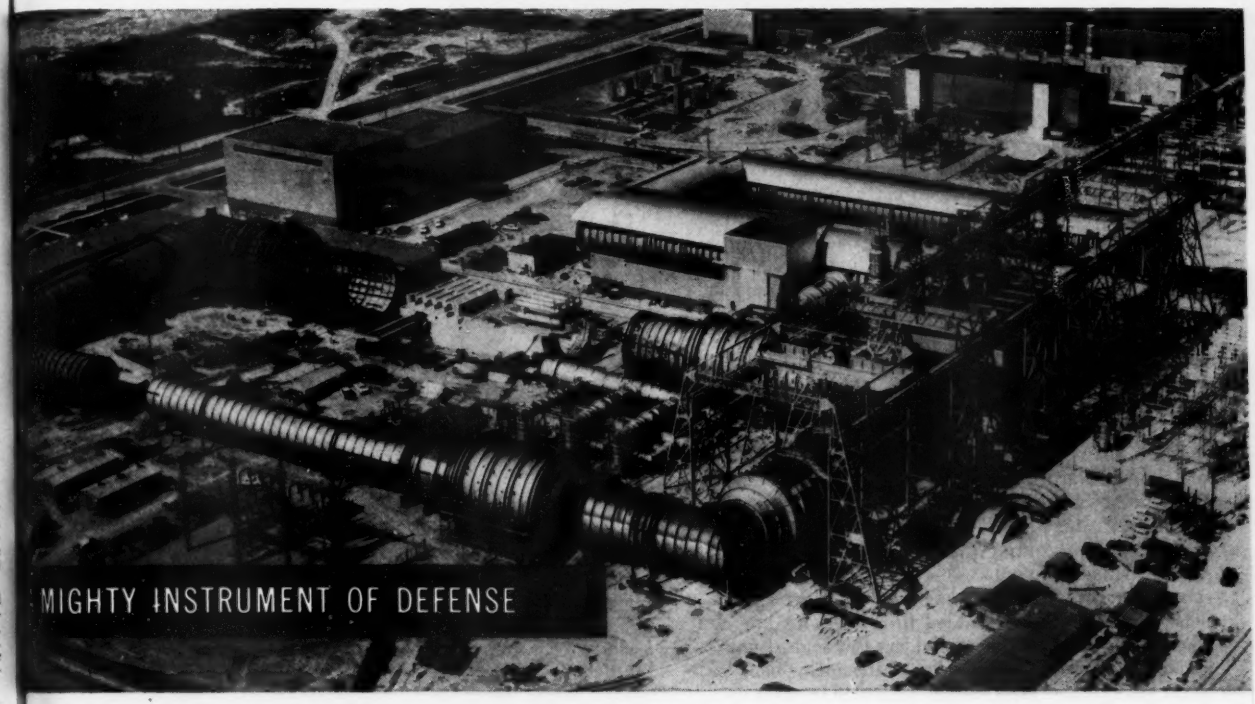
One of the tremendous coolers (right) required in the Supersonic circuit—55′ in diameter.

Transonic return duct No. 2 (below), with compressor and motor area under craneway in background.





Steel Platework by Pittsburgh-Des Moines



The Propulsion Wind Tunnel Facility at Tullahoma, Tennessee

The two largest wind tunnels of their speed in the country are shown built and under construction by PDM in the picture above. The Transonic Tunnel, now in operation, and the Mach 5 Supersonic Tunnel going up beside it each have interchangeable test sections 16′ x 16′ x 40′ long—a measure of the great size of this massive project. The size and complexity of the work are in turn a measure of Pittsburgh-Des Moines' ability to meet dependably your most exacting platework requirements. Write us for engineering consultations and preliminary estimates on your forthcoming projects.

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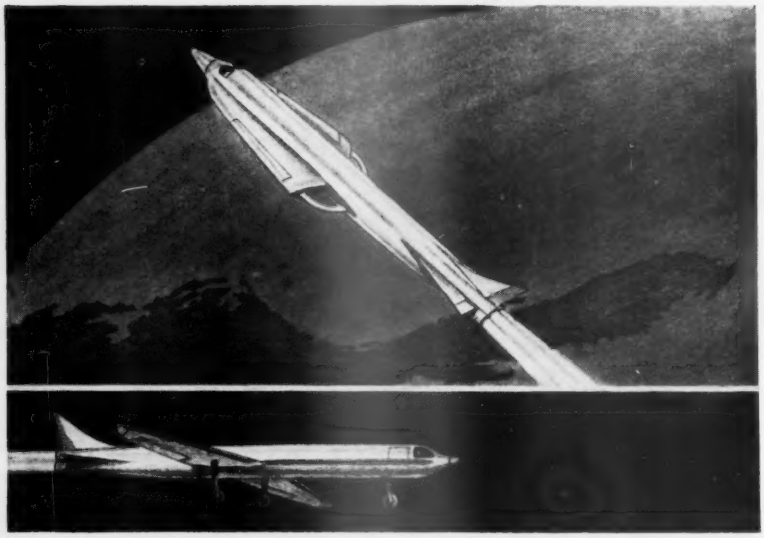

brings 'em back alive

Today's burning problem in space flight is how to ease a rocket safely back to earth, without being consumed by the metal-melting friction of our dense atmosphere. Design Engineer Carl J. Rauschenberger's ingenious suggestion is a pair of wings, locked forward at blast-off, later folded back into flying position (insert) by hydraulic cylinder controls for a slow, safe descent. Mr. Rauschenberger also envisions a retractable glass nose cone, heatproof to withstand the take-off, drawn back to admit air to a jet engine on the return flight.

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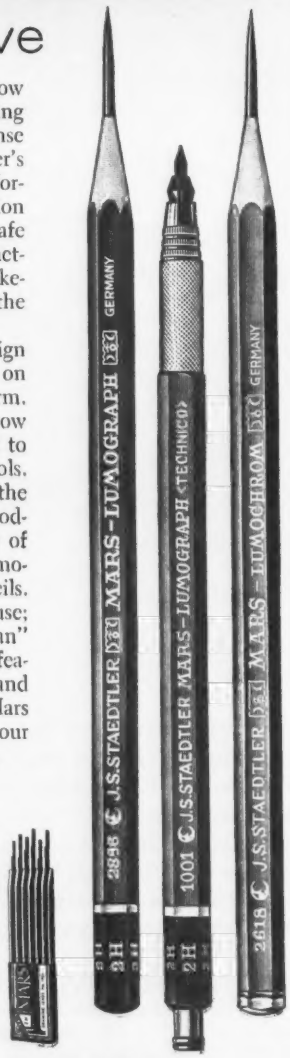

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In German. Investigation of the possibility of designing an open-type rotor with blades curved backwards in the case of known circulation distribution. Includes development of a successive approximation method based on the singularity method.

Experiments on Chemical Kinetics in a Supersonic Nozzle. Peter P. Wegener, Jack E. Marte, and Carl Thiele. *J. Aero. Sci.*, Mar., 1958, pp. 205, 206. Development of a method for measuring fast, homogeneous gas reactions in a steady-state supersonic nozzle, and observations showing where a reaction is lagging with respect to chemical equilibrium throughout a steady-state flow field.

Stability & Control

A Note on the Equations of Motion for a Rigid Aircraft with Varying Mass. Kyuichiro Washizu. (*Japan Soc. Aero. Eng. J.*, Aug., 1957, pp. 215-218.) Translation. Paper 892. 10 pp.

A Flight Investigation of the Effects of Varied Lateral Damping on the Effectiveness of a Fighter Airplane as a Gun Platform. Helmut A. Kuehnel, Arnold R. Beckhardt, and Robert A. Champine. *U.S., NACA TN 4199*, Jan., 1958. 30 pp. Tests on an aircraft equipped with a device for varying the lateral damping and a gunsight employing a fixed reticle and a gyro computing reticle. A brief investigation is included on a fixed telescope sight, under normal, increased, and decreased damping.

Wings & Airfoils

An Investigation of Four Wings of Square Plan Form at a Mach Number of 6.9 in the Langley 11-inch Hypersonic Tunnel. Charles H. McLellan, Mitchel H. Bertram, and John A. Moore. *U.S., NACA Rep. 1310*, 1957. 18 pp. Supt. of Doc., Wash., $0.25.

Establishment of Lift on an Aerofoil with a Jet Flap. II—Wing of Finite Span with Trailing Edge Jet. Appendix I—**Calculation of Jet Slope and of the Corresponding Radius of Curvature at the Trailing Edge.** Appendix II—**Component of Relative Velocity on the Section.** Appendix III—**Derivation of m_1 (ξ).** Appendix IV—**Corrections to the Aspect Ratio When the Wing is Interrupted by a Fuselage.** Appendix V—**Relation Governing Shedding of Elementary Vortices.** R. Hirsch. *Aircraft Eng.*, Jan., 1958, pp. 11-19.

Experimental Investigation of the Pressure Distribution at the Centre-Section of a Sweptback Wing at High Subsonic Speeds. T. E. B. Bateman and A. J. Lawrence. (*Gt. Brit., RAE Rep. Aero. 2556*, Aug., 1955.) *Gt. Brit., ARC CP 367*, 1957. 35 pp. BIS, New York, $0.90.

Quelques Résultats sur les Ailes Delta Portantes à Trainée Minimum en Régime Supersonique. P. Germain and R. Gibault. *La Recherche Aéronautique*, Nov.-Dec., 1957, pp. 54-56. In French. Presentation of results for minimum-drag delta wings in supersonic flow.

Three-Dimensional Transonic Flow Theory Applied to Slender Wings and Bodies. Max. A. Heaslet and John R. Spreiter. *U.S., NACA Rep. 1318*, 1957. 29 pp. 32 refs. Supt. of Doc., Wash., $0.35. Re-examination of the derivation of integral equations giving special attention to conditions resulting from shock waves and to the reduction of relations to special forms necessary for the discussion of sonic flow.

Lift and Rolling Moment on a Slender Wing-Body Combination with a Deflected Tip Control. John F. Clarke. *J. Aero. Sci.*, Mar., 1958, pp. 203-205. Calculations based on the slender-body approximation.

Aeroelasticity

On Two-Dimensional Panel Flutter. Y. C. Fung. (*IAS Natl. Summer Meeting, Los Angeles, June 17-20, 1957, Preprint 749.*) *J. Aero. Sci.*, Mar., 1958, pp. 145-160. 34 refs. OSR-supported investigation.

On Panel Flutter and Divergence of Infinitely Long Unstiffened and Ring-Stiffened Thin-Walled Circular Cylinders. Appendix A—**Steady Linearized Flow Past a Stationary Deformed Cylinder.** Appendix B—**Air Forces on a Cylinder in Divergent Oscillation.** Appendix C—**Equilibrium of Unstiffened Cylinder-Flügge's Equation.** Appendix D—**Importance of Damping in Unstiffened Cylinder.** Robert W. Leonard and John M. Hedgepeth. *U.S., NACA Rep. 1302*, 1957. 19 pp. 16 refs. Supt. of Doc., Wash., $0.25.

Influence de l'Amortissement Interne sur la Vitesse Critique de Flottement. P. Salaün. *La Recherche Aéronautique*, Nov.-Dec., 1957, pp. 19-25. In French. Investigation of the effect of internal damping on the critical flutter speed. Includes application to the aeroelastic system, treated as a special case, and presentation of two examples emphasizing the unfavorable effect of internal damping.

Ob Ustoichivosti Periodicheskikh Dvizhenii v Odnom Spetsial'nom Sluchae. V. M. Starzhinskii. *Prikl. Mat. i Mekh.*, Sept.-Oct., 1957, pp. 720-722. In Russian. Extension of Liapunov's method for estimating the characteristic constant to the more general problem of two linear first-order equations with periodic lumped-constant

(*Continued on page 94*)

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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AERODYNAMICS

Aerothermodynamics

TEMPERATURE DISTRIBUTION STUDIES IN THE TURBULENT BOUNDARY LAYER FOR COMPRESSIBLE FLOW WITHOUT HEAT TRANSFER. E. H. Alford. Texas U. DRL Rep. 421 (AFOSR TN 58-4) [AD 148043], Jan., 1958. 49 pp. Extension of Van Driest's boundary layer theory and modification of its equation in an attempt to account for the Prandtl Number not being unity. The modified theory is applied to existing data at Mach Numbers of 2.00, 2.50, and 5.00. A study is made on the effect of temperature recovery coefficient, Mach Number, and Reynolds Number upon an introduced parameter representing the modified theory. It is determined that the theory accounts for a variable Prandtl Number for turbulent flow and can be used to predict the temperature distribution with reasonable accuracy in a compressible turbulent boundary layer for the case of zero heat transfer.

MEASUREMENTS OF THE EFFECT OF SURFACE COOLING ON BOUNDARY LAYER TRANSITION ON A 15° CONE. I - TESTS AT M = 2 AND 3 IN AN 8 in. x 9 in. WIND TUNNEL AT R.A.E./BEDFORD. Appendix I - THERMOCOUPLE INSTALLATION AND CALIBRATION. Appendix II - MODEL COOLING APPARATUS. Appendix III - SURFACE CONDITION IN THE NEIGHBOURHOOD OF THERMOCOUPLE JUNCTIONS ON THE HEAT TRANSFER CONE. A. C. Browning, J. F. W. Crane, and R. J. Monaghan. Gt. Brit., RAE TN Aero.2527, Sept., 1957. 41 pp. 11 refs. Test results show that when the ratio (surface temperature ahead of transition/surface temperature for zero heat transfer) is deduced from 1.0 to 0.88, the transition Reynolds Number at zero incidence is increased by a factor of about 1.8 for a local Mach Number 1.86 and by a factor of 1.24-1.43 for Mach Number 2.81. The spread of the latter factor arose from alternative estimates of transition Reynold Number under zero-heat-transfer conditions, since at Mach Number 2.81 this Reynolds Number is dependent on stagnation pressure. When the cone is set at an incidence of 2°, transition on the windward generator moved aft with cooling at about the same rate as is found in the zero incidence tests at each Mach Number.

THE AXISYMMETRIC FREE-CONVECTION TEMPERATURE FIELD ALONG A VERTICAL THIN CYLINDER. F. R. Hama and J. V. Recesso. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-116 (AFOSR TN 58-25) [AD 148064], Jan., 1958. 87 pp. 17 refs. Theoretical and experimental investigation to study the effect of strong transverse curvature on boundary-layer problems. A theory is developed as an extension of the Glauert-Lighthill-Pohlhausen solution for any value of the x - parameter. Temperature profiles are measured at several sections along an electrically-heated brass cylinder, and the local heat-transfer coefficients agree well with theory. This, in turn, justifies the theories of laminar boundary layer along a thin cylinder developed by Glauert and Lighthill and by others. The location of laminar-turbulent transition is estimated from the temperature profiles and by a hot-wire observation. Transition is found to be delayed considerably as compared with that in the two dimensional case.

RECOVERY TEMPERATURES AND HEAT TRANSFER NEAR TWO-DIMENSIONAL ROUGHNESS ELEMENTS AT MACH 3.1. P. F. Brinich. US, NACA TN 4213, Feb., 1958. 20 pp. Experimental investigation at a Mach Number of 3.1 on a hollow cylinder and a cone-cylinder model showing the effect of single and multiple two-dimensional roughness elements on temperature and pressure distribution as well as on heat transfer. Abrupt perturbations in surface temperature occur in the neighborhood of the elements in the case of a turbulent boundary layer, but are absent for the laminar case. The type of perturbation depends on the element shape, forward-facing wedges giving

the lowest temperature immediately behind the element and forward-facing steps the highest. For a turbulent boundary layer the heat-transfer rate behind the wedge element is less than that obtained immediately ahead of the element.

HEAT TRANSFER THROUGH THE LAMINAR BOUNDARY LAYER ON A CIRCULAR CYLINDER IN AXIAL INCOMPRESSIBLE FLOW. D. E. Bourne and D. R. Davies. Quart. J. Mech. & Appl. Math., Feb., 1958, pp. 52-66. Presentation of a method for calculating the heat-transfer rate distribution when the cylinder surface is at a constant temperature. A series solution, valid for small downstream distances from the nose, has been obtained previously by Seban, Bond, and Kelly. This is now extended by deriving an asymptotic series solution, valid at large downstream distances, and bridging the gap between these two series solutions by an approximate solution, based on the method used recently by Davies and Bourne to calculate heat transfer from a flat plate. The calculation is used to demonstrate the effect of curvature and of Prandtl Number on the local rate of heat transfer at various downstream distances by comparison with the corresponding flat plate results.

STEADY TEMPERATURE OF A PLANE PLATE IN A REACTING GAS FLOW. E. P. Vaulin. Sov. Phys. - Dokl., Mar.-Apr., 1957, pp. 187-191. Translation. Presentation of exact solutions for the differential equations of the boundary layer of reacting gas mixtures with different physical properties, in order to obtain a formula for the steady temperature of a plane plate which can be used at high speeds, or when the heat of friction is comparable with the heat evolved in the chemical reaction. Also obtained are the concentration and temperature profiles for heterogeneous reactions in a region of diffusion.

ESTIMATION OF TURBULENT HEAT TRANSFER AT THE SONIC POINT OF A BLUNT-NOSED BODY. M. Sibulkin. Convair Sci. Res. Lab. RN 7, Oct., 1957. 35 pp. 26 refs. Derivation of an equation for the convective heat transfer in terms of conditions at the sonic point. The heat transfer at the stagnation point for the case of a perfect gas and for the dissociated air flow occurring at hypersonic flight velocities is also obtained. For rapid estimation purposes, a "very approximate solution" is developed for hypersonic speeds, involving only the free-stream velocity and density and the radius of curvature at the sonic point. The results obtained from the different solutions are compared for a sample calculation. A method for determining the flow conditions in terms of an average isentropic exponent is also presented, leading together with an assumed Newtonian pressure distribution to an equation for the inviscid-flow velocity gradient at the sonic point.

THE EFFECTS OF A SOUND WAVE ON THE COMPRESSIBLE BOUNDARY LAYER ON A FLAT PLATE. C. R. Illingworth. J. Fluid Mech., Feb., 1958, pp. 471-493. 10 refs. Investigation of the boundary layer of a hot flat plate which is fixed at zero incidence in a slow stream carrying a progressive sound. Formulas are obtained for the skin friction and the heat transfer in the extreme cases where the frequency is very low and very high. In addition, different methods of simplifying the boundary-layer equations in unsteady compressible flow are briefly compared.

Boundary Layer

BOUNDARY LAYER GROWTH ON A SPINNING BODY: ACCELERATED MOTION. Y. D. Wadhwa. Philos. Mag., 8th Ser., Feb., 1958, pp. 152-158. Investigation of the boundary-layer motion when a body of revolution starts moving along its axis of symmetry and simultaneously rotates about it with a velocity varying as the nth power of time. It is found that the separation is delayed by acceleration and that the time elapsing before separation first takes place is lessened by increasing the spin velocity.

FLOW IN THE LAMINAR BOUNDARY LAYER NEAR SEPARATION. B. S. Stratford. Appendix I - THE SOLUTION IN THE NEIGHBOURHOOD OF THE SINGULARITY AT $x = x_0$, WITH FINITE PRESSURE GRADIENTS. G. E. Gadd. Gt. Brit., ARC R&M 3002, 1957. 27 pp. 21 refs. BIS, New York, $1.44. Derivation of a simple formula for the separation of the laminar boundary layer. The method of derivation and a key test show that it is reasonably accurate and of general application, including particularly the range of sharp pressure gradients and small pressure rises to separation. A partially new exact solution is also found for the boundary-layer equations of motion, as well as the pressure distribution for continuously zero skin friction, this pressure distribution being expected to attain any given pressure rise in the shortest distance possible for a given boundary layer, provided that there is neither transition nor boundary-layer control.

BOUNDARY-LAYER TRANSITION ON AN OPEN-NOSE CONE AT MACH 3.1. P. F. Brinich. US, NACA TN 4214, Feb., 1958. 11 pp. Comparison of transition locations for an open-nose cone, a conventional sharp cone, and a hollow cylinder showing that transition locations on the open-nose cone and the hollow cylinder are identical but differ greatly from those on the sharp cone. It is supposed that this is due to the essentially two-dimensional character of the boundary layer at the leading edge of the open-nose cone. Bluntness effects on the open-nose cone are quite similar to those on the hollow cylinder, and transition is displaced downstream 2.2 times the sharp-cone transition distance by blunting the tip.

AN ANALYSIS OF THE TURBULENT BOUNDARY-LAYER CHARACTERISTICS ON A FLAT PLATE WITH DISTRIBUTED LIGHT-GAS INJEC-

TION. M. W. Rubesin and C. C. Pappas. US, NACA TN 4149, Feb., 1958. 43 pp. 16 refs. Derivation of the basic turbulent boundary-layer equations for a binary gas system as well as the modified Reynolds analogies between momentum, mass, and heat transfer. The effect of foreign gas injection on skin friction and heat transfer of a nearly isothermal boundary layer is estimated using the mixing length theory. Numerical results are given for hydrogen and helium. It is found that they have no effects on the temperature-recovery factor, and that from the viewpoint of reducing skin friction by injection, helium and hydrogen are generally 2.5 and 5.0 times as effective as air on a mass basis; from the viewpoint of reducing the Stanton Number, they are generally 2.4 and 5.2 times as effective as air.

THE ACCURACY OF MEASUREMENT OF TURBULENT SKIN FRICTION BY MEANS OF SURFACE PITOT-TUBES AND THE DISTRIBUTION OF SKIN FRICTION ON A FLAT PLATE. Appendix I - THE INFLUENCE OF THE TURBULENT FLUCTUATING VELOCITIES ON THE VON KÁRMÁN MOMENTUM EQUATION FOR TWO-DIMENSIONAL FLOW. R. A. Dutton. Gt. Brit., ARC R&M 3058, 1957. 18 pp. 16 refs. BIS, New York, $0.99. Experimental investigation at a constant Reynolds Number of two-dimensional turbulent boundary-layer flow with zero pressure gradient on a smooth flat plate 6 ft. long, spanning the working-section of a return-circuit wind tunnel. Transition is promoted by trip wires and glass-paper strips. The general momentum equation is used in conjunction with measurements of skin friction by Preston's method to obtain increments in momentum thickness which could be compared with the measured values. It is shown that Preston's method gives the correct skin friction.

A TURBULENT ANALOG OF THE STEWARTSON-ILLINGWORTH TRANSFORMATION. F. E. C. Culick and J. A. F. Hill. J. Aero. Sci., Apr., 1958, pp. 259-262. 11 refs. Application of the Stewartson-Illingworth transformation to the integral momentum equation for compressible boundary layer flow, leaving the x-coordinate transformation unspecified. It is shown that the transformed equation is the integral momentum equation for incompressible flow if (a) the effect of compressibility on the boundary-layer shape parameter H can be represented by $H + 1 = (H_i + 1)(T_0/T_e)$ and (b) the x-coordinate transformation is chosen to be suitably related to the ratio of the skin-friction coefficients in compressible and incompressible flows. Experimental evidence is presented which shows that condition (a) is satisfied for turbulent boundary layers up to Mach Number 5. An x-transformation is chosen according to (b) and an equation is presented which gives the turbulent boundary-layer growth of compressible flow in terms of a simple quadrature.

FINITE DIFFERENCE METHODS OF SOLUTION OF THE VON MISES BOUNDARY LAYER EQUATION WITH SPECIAL REFERENCE TO CONDITIONS NEAR A SINGULARITY. A. R. Mitchell and J. Y Thomson. ZAMP, Jan. 25, 1958, pp. 26-37. Study of the separation point of the boundary-layer flow along a flat plate against an adverse pressure gradient. It is shown that the singularity of the von Mises equation at the plate in Görtler's problem can be overcome by using an appropriate expansion for the velocity in the vicinity of the plate. As a result, conditions at the plate can be deduced from the values of the velocity in the boundary layer obtained from a step-by-step finite difference procedure.

THE BEHAVIOUR OF A PITOT TUBE IN TRANSVERSE SHEAR. Appendix - THE ESTIMATION OF DISPLACEMENT CORRECTIONS FOR A PITOT LARGE COMPARED WITH THE WIDTH OF THE WAKE. P. O. A. L. Davies. J. Fluid Mech., Feb., 1958, pp. 441-456. 10 refs. Experimental investigation on the displacement of the total-head profile in shear flow from its true position when it is measured with a flat-ended round pilot tube. The experiments show that at least two forms of displacement may exist depending on the flow conditions. In a wake the desplacement of the effective center of pressure towards the higher velocity is found to obey a law deduced theoretically by Hall, provided that the changes in flow direction are not large. In the presence of large eddies the behavior of the pitot is further modified by its characteristics in yaw. This introduces a total-head error reducing the observed total head. In a turbulent boundary layer the experiment shows that the displacements are of an order of magnitude smaller than in a wake and can be regarded as negligible for a round pitot, even when it is touching the wall.

Control Surfaces

THE EFFECT OF ENTRAINMENT UPON A JET-FLAPPED AIRFOIL. H. S. London. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 57-761) [AD 136750], Dec., 1957. 44 pp. Development of a model for a straight two-dimensional incompressible turbulent jet issuing into a free stream and calculation of the entrained mass flow. The jet is then replaced by a distribution of sinks which gives the same entrainment. With this sink distribution the potential flow is calculated over a thin bi-parabolic airfoil at zero angle of attack, with the jet at zero deflection angle, and from this the pressure drag due to entrainment is determined. It is found that although this drag increases with increasing jet thrust, the ratio of entrainment drag to thrust decreases and is of the order of 0.2-0.3 times the thickness ratio of the airfoil. It is further shown that with the jet deflected, the entrainment also induces a negative increment in circulation lift.

Fluid Mechanics & Aerodynamic Theory

THREE-DIMENSIONAL MOTIONS IN CLOSED REGIONS AT LARGE REYNOLDS NUMBERS. W.

XUM

W. Wood. Australia, ARL Rep. A.106, Nov., 1957. 16 pp. Analysis of the steady motions of a slightly viscous incompressible fluid with closed stream lines. A unique approximation is defined for the case of unclosed streamlines using Euler's equations, but for motions with closed streamlines these equations are inadequate. This indeterminacy is analysed, and a method is developed for two-dimensional motions and extended to three dimensions.

A THEORETICAL STUDY OF THE RECOMBINATION KINETICS OF ATOMIC OXYGEN. Appendix A - ESTIMATE OF k_1 BY COLLISION-RATE THEORY. Appendix B - ESTIMATES OF k_1 BY ABSOLUTE-REACTION-RATE THEORY. Appendix C - OXYGEN RECOMBINATION WITH FINITE COOLING RATES. S. T. Demetriades and Milton Farber. Aerojet-Gen. TN 21 (AFOSR TN 58-18) [AD 148057], Nov. 8, 1957. 60 pp. 42 refs. Analysis to determine favorable conditions for measuring the recombination rates of atomic oxygen. A rate constant (k_1) has been derived theoretically for the oxygen-recombination mechanism, $O + O + M \longrightarrow O_2 + M$, on the order of 10^{15} to 10^{16} $cc^2/mole^2$-sec., depending on the temperature. For a recombination rate of this magnitude, static experiments can be performed in the range of temperature from 1,500 to 2,000°K. and pressures of the order of 10^{-3} atmos., provided that the wall recombination is not faster than predicted by the rate of collisions of colliding oxygen atoms with the wall. The present estimate of the rate of oxygen recombination is compared with three factors: previous estimates; the rate of oxygen-molecule production due to wall recombination; and the ozone-recombination mechanism, $O_3 + O \longrightarrow 2O_2$.

CONICAL FLOW PARAMETERS FOR AIR IN DISSOCIATION EQUILIBRIUM: FINAL RESULTS. M. F. Romig. Convair Sci. Res. Lab. RN 14, Jan., 1958. 58 pp. 11 refs. Numerical integration of the Taylor-Maccoll equation describing supersonic flow about cones for semi-vertex angles from 20° to 50°, velocities from 10,000 to 32,000 ft/sec., free stream pressures from 10^{-4} to 10^{-1} atmospheres, and a nominal free stream temperature of 491.7°R. (273.16°K.). The air between the shock wave and the body is assumed to be in instantaneous thermal and chemical equilibrium. Values are tabulated for the aerodynamic and thermodynamic flow properties, electron density, velocity, and Mach Number directly behind the shockwave and on the cone surface streamline. These properties are correlated using the hypersonic similarity parameter with an error of less than 1%, and graphs are presented of the conical flow properties as functions of $M_1 \sin\theta_v$ (M_1 being the free stream Mach Number and θ the cone semi-vertex angle) and free stream pressure. Empirical equations based on the similarity rule are given for the shock-wave angle and pressure coefficient.

FINAL REPORT SUMMARIZING RESEARCH IN RATE OF HIGH-SPEED REACTIONS. W. H. Wurster. Cornell Aero. Lab. Rep. AD-959-A-2 (AFOSR TR 58-8) [AD 148054], Jan., 1958. 19 pp. 14 refs. Discussion of the principles of the single temperature pulse shock tube for the study of high-speed chemical reactions. This facility has been employed to investigate the kinetics of the $N_2 + O_2 \rightleftharpoons 2\,NO$ reaction between 2,000°K. and 3,000°K. These kinetics have been proven to be consistent with the chain mechanism proposed by Zeldovich. A separate study of the relaxation time for oxygen dissociation at 2,000 - 4,000°K. yielded values which confirm the validity of the chain mechanism for the NO reaction.

EFFECT OF OXYGEN RECOMBINATION ON ONE-DIMENSIONAL FLOW AT HIGH MACH NUMBERS. S. P. Heims. US, NACA TN 4144, Jan., 1958. 52 pp. 32 refs. Theoretical analysis of air flow in a stream tube, in which oxygen dissociation and recombination occur. The theory developed permits a finite reaction rate which varies from point to point along the flow. An estimate of the reaction rate is made and a numerical example is worked out for a stream tube with a shape that might be expected for air flowing around a blunt body. Comparative relaxation times of the oxygen dissociation-recombination reaction in relation to molecular vibrations are also analyzed, and it is shown that it is not generally true that vibrational relaxation times are short compared to the time characteristic of chemical reaction. Some relaxation time values are calculated, and a method is given for estimating the effect of vibrational lag for relatively long vibrational relaxation times.

OB OBTEKANII NAMAGNICHENNYKH TEL PROVODIASHCHEI ZHIDKOST'IU. A. G. Kulikovskii. AN SSSR Dokl., Nov. 11, 1957, pp. 199-202. In Russian. Investigation of the flow of conducting liquid past magnetized bodies with cavities containing the magnetic field. The case of stationary flow is considered under the assumption of a cavity filled with liquid. Includes the cases of: flow of an incompressible fluid past a plane magnetic dipole perpendicular to the stream; constant-density supersonic flow over the surface of a wedge, perpendicular to the rib of the wedge; and constant-density supersonic flow over the surface of a cone, normal to the generatrix of the cone.

PLASMA HEATING OF HYPERSONIC GAS FLOW. R. L. Chuan. USCEC Rep. 56-202 (AFOSR TN 57-762) [AD 136751], Dec. 31, 1957. 21 pp. Discussion of a proposal to add energy to the electrons in the air downstream of the throat in a hypersonic wind tunnel by high frequency electrodeless discharge, and to allow electron energy to go into random kinetic energy of the molecules in the decay process. The decay process is examined in an attempt to channel as much of the electron energy as possible into raising the temperature of the gas by preventing losses by the ambipolar loss mechanism. Inhibition of ambipolar

diffusion by means of an axial, constant magnetic field is examined, as well as the attendant possibility of having such an inhibiting effect nullified by drain diffusion resulting from hydromagnetic instability.

THE PROSPECTS FOR MAGNETO-AERODYNAMICS. E. L. Resler, Jr., and W. R. Sears. (IAS Natl. Summer Meeting, Los Angeles, June 17-20, 1957.) J. Aero. Sci., Apr., 1958, pp. 235-245, 258. 10 refs. Formulation of equations describing the flow of an electrically conducting fluid in the presence of electric and magnetic fields. In order to estimate the probable significance of magneto-aerodynamic effects, some data on conductivity of pure and "seeded" air are first examined. Dimensionless quantities representing the ratios of forces and of currents are then formed and their values studied for conditions of light in the atmosphere. Some examples of magneto-hydrodynamic and magneto-gasdynamic effects in simple flows are also given.

EXPERIMENTAL THERMAL CONDUCTIVITIES OF THE $N_2O_4 \rightleftarrows 2NO_2$ SYSTEM. K. P. Coffin and Cleveland O'Neal, Jr. US, NACA TN 4209, Feb., 1958. 22 pp. 18 refs. Measurement of thermal conductivity by a hot-wire technique at temperatures between 20° and 215°C. and pressures from 1/3 to 1 atmosphere; approximate values are obtained at pressures as low as 0.02 atmosphere from 20° to 80°C. Experimental values are in good agreement with values calculated so as to include the effects of dissociation; dissociation produces an order-of-magnitude increase in conductivity.

EXPERIMENTS AT M = 1.41 ON ELLIPTIC CONES WITH SUBSONIC LEADING EDGES. E. W. E. Rogers and C. J. Berry. Gt. Brit., ARC R&M 3042, 1957. 41 pp. 44 refs. BIS, New York, $2.16. Wind-tunnel study on six cones forming two families of models. In the first, the vertex angle in the plane of the major axes of the elliptic cross-sections is maintained constant at 60° and the ratio between the minor and major axes varied; in the second family, the minor axis is constant and the vertex angle has values of 30°, 60°, and 90°. Two cones from the first family are pressure-plotted at incidences up to 15°, the resulting pressure distributions being integrated to give the lift and pressure drag arising from the curved surfaces of the cones. Lift, drag, and center-of-pressure position are measured for all models on a strain-gage balance.

INCOMPRESSIBLE NEWTONIAN HYPERSONIC FLOW AROUND A SPHERE. R. D. Linnell. Convair Sci. Res. Lab. RN 5, June, 1957. 27 pp. Preliminary analysis of constant-density hypersonic inviscid flow around spheres. The surface velocity is obtained by assuming that the surface overpressure varies as the sine of the local slope angle. The surface velocity and shock boundary conditions are used to determine the constants in a series solution of the continuity equation, thus giving a prediction of the axial shock separation distance. It is shown that the equations for surface-velocity gradient and the separation distance can be used for quasi-static real gas conditions. The predictions correlate adequately with perfect gas condition test data.

ANALYTICAL BOUNDARY CONDITIONS FOR HYPERSONIC FLOW AROUND A SPHERE. R. D. Linnell. Convair Sci. Res. Lab. RN 4, 1957. 35 pp. Theoretical investigation of the shock boundary conditions to be satisfied at the unknown location of the detached shock wave, and determination of functional relations to be satisfied at the shock for axial symmetric spherical coordinates. A derivative matching procedure is considered for use in determining constants in a general solution. The procedure is shown to be extendible to any desired accuracy. Methods for obtaining a closed mathematical problem with cruder approximations than the three-derivative one are presented, as well as a method for obtaining an implicit equation for the shock applicable when solutions for u (radial component of velocity) and v (circumferential component of velocity) are known.

ON THE MOTION OF A SPHERE ALONG THE AXIS OF A ROTATING FLUID. K. Stewartson. Quart. J. Mech. & Appl. Math., Feb., 1958, pp. 39-51. Analysis of a sphere in an unbounded fluid rotating with uniform angular velocity, using the assumption that the fluid is undisturbed far upstream. It is shown that no wave-like components can then occur upstream of the body. The stream function ψ and the drag are found for various values of the Rossby number ka. When the Rossby Number = 5.76 both these quantities become infinite everywhere and it is inferred that the fluid cannot be undisturbed far upstream when ka $\geq$ 5.76. It is probable that cylindrical flow which must then be present must also occur at smaller values of ka whose lower bound is unknown.

ON THE DRAG OF A SPHERE AT EXTREMELY HIGH SPEEDS. V. C. Liu. J. Appl. Phys., Feb., 1958, pp. 194, 195. Army-sponsored derivation of the formula for the pressure-drag coefficient, assuming that the nose of the shock contour follows exactly the frontal half of the spherical surface and the local pressure on the frontal spherical surface corresponds to the pressure behind the shock wave, after the statistical equilibrium between the various degrees of freedom of the molecule has been reached. The chemical dissociation of the molecules behind the shock wave is taken into account in the analysis, and the theoretical results of the drag coefficient of the spheres agree with the corresponding available measured values within the experimental error for the range of Mach Numbers between 5 and 10.

UNSTEADY FLOW INCLUDING SHOCK WAVES AROUND A SLENDER TWO-DIMENSIONAL BODY

XUM

MOVING AT HIGH SUPERSONIC SPEEDS. G. R. Russell. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 57-759) [AD 136748], Sept., 1957. 39 pp. 13 refs. Development of approximate solutions by transforming a time-dependent physical boundary condition into a "piston" plane with one less dimension. The unsteady one-dimensional problem is solved there with a second-order theory, and the result is transformed back into the physical plane. It is shown that one solution in the "piston" plane represents a family of possible flow patterns in the physical plane, and every solution depends on the history of the moving body. Examples are obtained for a plunging flat plate, a wedge moving with constant angular velocity, and an oscillating wedge.

AN EXPERIMENTAL INVESTIGATION OF THE FLOW OVER SIMPLE TWO-DIMENSIONAL AND AXIAL SYMMETRIC BODIES AT HYPERSONIC SPEEDS. I. E. Vas, S. M. Bogdonoff, and A. G. Hammitt. Jet Propulsion, Feb., 1958, pp. 97-104. 24 refs. Presentation of wind-tunnel test data for flat and semicircular leading edges for Mach Numbers between 11 and 19. The shock shape, detachment distance, and sonic point on the shock are found from the Schlieren pictures. Similar pressure distributions are obtained for corresponding two-dimensional and axial symmetric bodies.

ZUR AERODYNAMIK DER RUMPFKÖRPER BEI KOMPRESSIBLER STRÖMUNG. Erich Truckenbrodt. ZFW, Jan., 1958, pp. 15-20. In German. Study of the aerodynamics of bodies in compressible flow, using the Prandtl-Glauert transformation for bodies in subsonic and supersonic flow. In the subsonic case the problem is reduced to the solution of a corresponding incompressible problem ($M = 0$), in the supersonic case to that of a corresponding problem with $M = \sqrt{2}$. It is shown that the pressure, lift, and moment distribution are independent of the Mach Number.

A MODEL OF SUPERSONIC FLOW PAST BLUNT AXISYMMETRIC BODIES, WITH APPLICATION TO CHESTER'S SOLUTION. M. D. van Dyke. J. Fluid Mech., Feb., 1958, pp. 515-522. Analysis in which a simple approximate model is set forth for the flow field between the nose of a blunt body of revolution and its detached shock wave. The model tends to explain the poor convergence of Chester's solution, based on an improvement of the Newtonian approximation. It suggests a modification of his series for the body shape which appears to improve its convergence considerably.

SCURGERI CONICE DE ORDIN SUPERIOR ÎN JURUL ARIPILOR TRIUNGHIULARE SUBŢIRI SAU DE GROSIME SIMETRICĂ. E. Carafoli and M. Ionescu. Stud. Cerc. Mec. Aplic., No. 3, 1957, pp. 677-701. In Rumanian, with summaries in English and Russian. Investigation of high-order conical flows around thin triangular wings or wings of variable thickness. Based upon a hydrodynamic analogy, it is shown that any high-order homogeneous motion can be reduced to the problem of a series of singularities located in the Busemann plane along the wedges separating two regions with different vertical velocity distributions. These singularities, required by the physical flow conditions in the immediate proximity of the wedge, have a hydrodynamic character (sources, doublets, etc.), and are reproduced in a conveniently chosen plane such that the problem of boundary conditions be a known problem of a two-dimensional motion. Thus, the axial disturbance velocities, due to a wedge or to subsonic leading edge of a thin wing, are established. The axial disturbance velocities around thick or thin wings with subsonic or supersonic leading edges are given in their general form.

THE CALCULATION OF THE DRAG IN PROBLEMS SOLVED BY THE HODOGRAPH METHOD. A. G. Mackie. Philos. Mag., 8th Ser., Feb., 1958, pp. 140-142. USAF-sponsored development of explicit formulas for the total drag on a class of obstacles placed in a uniform stream of an inviscid fluid when the stream function is given in terms of the velocity variables. These formulas are presented for incompressible flow and for the incompressible-flow equation.

ON THE VALIDITY OF CONTINUUM THEORY FOR SATELLITE AND HYPERSONIC FLIGHT PROBLEMS AT HIGH ALTITUDES. M. C. Adams and R. F. Probstein. Jet Propulsion, Feb., 1958, pp. 86-89. Estimation of the order of magnitude in establishing the flight conditions to which a continuum analysis should be applicable in the stagnation region of a blunt body. Differential equations are presented for the flow in the stagnation region for the flight regime where neither boundary layer theory nor free molecule theory are valid. The results of the study are applied to the problem of re-entry of a satellite, and it is concluded that a continuum analysis, with no slip at the body surface, is valid for flight conditions where heating is important.

MEASUREMENTS OF THE INTENSITY, INTEGRAL SCALE AND MICROSCALE OF TURBULENCE DOWNSTREAM OF THREE GRIDS IN A STREAM OF AIR. B. G. van der Hegge Zijnen. Appl. Sci. Res., Sect. A, No. 2-3, 1958, pp. 149-174. 15 refs. Investigation of the flow past iron-strip grids. The strips were 0.7, 1.2, and 1.0 cm. wide, respectively; and for most of the experiments the velocity of the wind tunnel was 1,200 cm./sec.

Internal Flow

SOME TESTS ON CASCADES OF COMPRESSOR BLADES FITTED WITH VORTEX GENERATORS. R. Staniforth. Gt. Brit., NGTE Memo. M.314, Jan., 1958. 18 pp. Experimental investigation showing that the fitting of vortex generators to the convex surface of compressor blades increases

the two-dimensional losses under all conditions. It is further shown that the vortex generators are, in fact, suppressing shock-induced flow separation, but that boundary layer separation still occurs at about 50% chord - probably due to the increased boundary layer thickness produced by the vortex generator drag, and that it is impossible to increase the drag critical Mach Number by means of vortex generators.

EXPERIMENTAL AND THEORETICAL INVESTIGATIONS OF THE FLOW OF AIR THROUGH TWO SINGLE-STAGE COMPRESSORS. J. H. Horlock. Gt. Brit., ARC R&M 3031, 1957. 36 pp. BIS, New York, $1.89. Investigation on the accuracy of theoretical predictions for actuator-disc performance carried out on an axial-flow-compressor test rig. This study involves the traversing of pressure and angle measuring instruments at the trailing edge and further downstream of blade rows, and comparisons of the axial velocity profiles obtained from these pressures and yaw angles at the various stations with theoretically predicted profiles. The changes in axial velocity profiles at the trailing edges of blade rows due to the interference effect of neighboring rows are also studied, both in the stalled and unstalled regions of operation.

SUBSONIC WIND-TUNNEL TESTS OF VARIOUS FORMS OF AIR INTAKE INSTALLED IN A FIGHTER-TYPE AIRCRAFT. Appendix I - MEASUREMENT OF INTERNAL DRAG. B. J. Prior and C. N. Hall. Gt. Brit., RAE Rep. Aero. 2576, Sept., 1957. 79 pp. 16 refs. Experimental investigation at Mach Numbers up to 0.93 to show how the longitudinal characteristics of a fighter-type aircraft are affected by the installation of air intakes in either the nose, fuselage sides, or wing-roots. It is seen that none of these intakes alter the lift or pitching moment characteristics significantly, but their effects on external drag vary, and only the nose intake avoids an increase which largely determines not only the critical Mach Number, and hence the behaviour at transonic speeds of the intake fairing, but also its sensitivity to spillage and aircraft attitude.

DESIGN OF A VARIABLE TEST SECTION HEIGHT SEMIFLEXIBLE NOZZLE FOR A LARGE MACH NUMBER RANGE. John Rosén and Gösta Rosander. SFAB TN 5, July 6, 1957. 22 pp. Presentation of nondimensional design parameters as functions of the Mach Number for nozzles of different maximum slope angles. From these curves all data necessary for designing a variable supersonic nozzle, adapted to the theoretical requirements within the whole Mach Number range, can be found. Two new design concepts are introduced for obtaining a theoretically correct nozzle at any Mach Number. One is the variable test section height, and the other a device for automatic variation of the boundary-layer correction with Mach Number.

SHAPE OF INITIAL PORTION OF BOUNDARY OF SUPERSONIC AXISYMMETRIC FREE JETS AT LARGE JET PRESSURE RATIOS. E. S. Love and L. P. Lee. US, NACA TN 4195, Jan., 1958. 29 pp. Calculations for jets exhausting into still air at large ratios of jet static pressure to stream static pressure from a conically divergent nozzle having a jet exit Mach Number of 2.5 and a semi-divergence angle of 15°. The calculations cover static-pressure ratios from about 60 to 42,000 and ratios of specific heats of 1.200, 1.400, and 1.667. Results indicate the size and shape of the jet to be expected at large pressure ratios, the effects of the ratio of specific heats, and the large initial inclinations for the boundary that are likely to be encountered by hypersonic vehicles at high altitude. A cursory examination of the propulsive jet behavior on a hypothetical rocket-propelled hypersonic vehicle indicates that feasible hypersonic vehicles may encounter within their operating range initial inclinations of the free-jet boundary approaching and exceeding 90°.

SUPERSONIC JET DEFLECTION. Appendix - DETERMINATION OF THE CENTRE OF PRESSURE. R. P. Fraser and P. N. Rowe. RAeS J., Jan., 1958, pp. 43-59. 24 refs. Experimental investigation on model nozzles to examine some of the possible means of effecting jet control and to obtain some data concerning the forces involved. The following four jet control methods are presented and compared: nozzle alignment, auxiliary side jets, compression deflection, and expansion deflection.

STRENGE LÖSUNGEN DER NAVIER-STOKES-GLEICHUNG FÜR ROTATIONSSYMMETRISCHE STRÖMUNGEN. Karlheinz Müller. DVL Bericht No. 47, Dec., 1957. 53 pp. Westdeutscher Verlag, Köln & Opladen. In German. Derivation of exact solutions of the Navier-Stokes equations for rotationally symmetric flows, covering any cone or nozzle angle and any viscosity, and discussion of rational solutions. The special cases of these strict solutions include the efflux of a round jet from a nozzle or suction through a small orifice.

ON THE DEFLEXION OF JETS BY AEROFOILS. L. C. Woods. Quart. J. Mech. & Appl. Math., Feb., 1958, pp. 24-38. Study of a two-dimensional jet of incompressible inviscid fluid which is deflected by an airfoil immersed in it. The relation between the airfoil incidence and jet deflection angle, the extent to which the airfoil displaces the jet from the position it would occupy in the airfoil's absence, and the ratio of fluid flowing above the airfoil to that flowing below are calculated. Other results, such as the velocity distribution over an airfoil and the shape of the free surface of the jet, are also given.

Performance

FLIGHT DEVELOPMENT OF THE AVRO CF-100 MARK 5 AIRCRAFT. D. C. Whittley.

RAeS J., Feb., 1958, pp. 118-122. Discussion of the improvements made in the wing aerodynamic characteristics of the CF-100 twin-jet fighter. Modifications to the wing include increase in aspect ratio, addition of vortex generators, and deflection of trailing edge flaps. The effect of flap deflection and addition of vortex generators on the aerodynamic characteristics of the wing are shown to be closely associated with interaction of the upper surface shock wave with the boundary layer. Performance gains are demonstrated at high subsonic speeds at high altitudes. Vortex generators improve the buffet boundary, while flap deflection increases aircraft ceiling and improves buffet boundary.

BETRACHTUNGEN ZUM REICHWEITENVERLUST BEIM KURVENFLUG. Siegfried Günter. ZFW, Jan., 1958, pp. 10-15. In German. Investigation of the energy loss due to steady flight along a curved path, and development of the corresponding equations for four flight problems, the thrust increase required to maintain steady curved-flight being given for two cases. The four non-steady curves in the case when thrust equals drag in level flight and is not increased at the beginning of the curved path are calculated for two representative engine characteristics of thrust and speed and two values of the parameter QF/G (sonic stagnation pressure x wing area/gross weight).

Stability & Control

WIND-TUNNEL INVESTIGATION OF EFFECT OF SWEEP ON ROLLING DERIVATIVES AT ANGLES OF ATTACK UP TO 13° AND AT HIGH SUBSONIC MACH NUMBERS, INCLUDING A SEMIEMPIRICAL METHOD OF ESTIMATING THE ROLLING DERIVATIVES. J. W. Wiggins. US, NACA TN 4185, Jan., 1958. 47 pp. 19 refs. Presentation of results of an investigation to determine the rolling derivatives for swept-wing-body configurations. The wing has sweep angles of 3.6°, 32.6°, 45°, and 60° at the quarter-chord line, an aspect ratio of 4, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free stream. Some tests are made of the 45° swept wing with fences located at the 65% -semispan station. It is shown that the variation of the damping-in-roll derivative with sweep angle at zero angle of attack is in fair agreement with the predictions, but contrary to predictions, the yawing moment and the lateral force both due to rolling, were positive and negative respectively throughout the angle-of-attack range. A method for estimating the yawing moment and lateral force is presented; it is applicable over large ranges of leading-edge radii, wing thickness, and Mach Number.

Wings & Airfoils

ZUR AERODYNAMIK DES RINGFLUGELS. II - DIE RUDERWIRKUNG. III - DER EINFLUSS DER PROFILDICKE. J. Weissinger. DVL Bericht No. 39; No. 42, Oct., 1957. 27; 44 pp. Westdeutscher Verlag, Köln & Opladen. In German. II - EORDC-sponsored investigation of the aerodynamics of annular wings covering the rudder effect. Includes: summary of previously derived formulas and derivation of tables for kernel functions, equivalent matrices, and their inverses; modification of the reciprocity rule of the airfoil theory for annular wings; and derivation of formulas for the radial force and moment distributions. Results indicate that the annular wing parameter L/D has a strong influence on the rudder effect. III - Study of the effect of profile thickness indicating the need for a vortex as well as a source distribution. Includes: tabulation of kernel functions of the integral equation for the calculation; presentation, in a form suitable for practical calculation, of the axial velocity for a circular cylinder with superimposed sources and vortices; presentation of tables for the most important cases so that for a given profile and wing form only a superposition operation is required; and indication that the velocity on the circular cylinder can be used to obtain the profile contour.

CALCULATED VELOCITY DISTRIBUTIONS AND FORCE DERIVATIVES FOR A SERIES OF HIGH-SPEED AEROFOILS. C. S. Sinnott. Gt. Brit., ARC R&M 3045, 1957. 31 pp. BIS, New York, $1.62. Determination of the velocity distribution over a number of two-dimensional airfoils at low incidence, using the polygon method of Woods. Lift slopes and aerodynamic centers at zero lift are also calculated, and some comparisons with experimental results are made, showing good agreement at zero incidence.

AERODYNAMISCHE PROBLEME BEI DER ENTWICKLUNG VOM UNTERSCHALL- ZUM ÜBERSCHALLTRAGFLÜGEL. Dietrich Fiecke. VDI Zeitschrift, Feb. 1, 1958, pp. 133-146. 25 refs. In German. Investigation of aerodynamic problems in the development from subsonic to supersonic wings, including a comparison of dimensional and geometric characteristics of wings of long-range transport, long-range bomber, and fighter aircraft. The main trends in parameter changes in relation to speed-regime increases are pointed out for each group; the aerodynamic theory is reviewed for subsonic, transonic, and supersonic flight; and the influence of wing plan form or aerodynamic behavior is illustrated for arrow, swept, and delta wings of different aspect ratios and profile thicknesses.

AN INVESTIGATION OF THE VELOCITY DISTRIBUTION AROUND THE NOSE OF THE AEROFOIL WITH A FLAP. I. H. Rettie. Gt. Brit., ARC R&M 3027, 1957. 15 pp. BIS, New York, $0.81. Determination of the velocity distribution around the nose of an NACA 0015-64 airfoil by experiment and of that around the nose of a Piercy 15/40 airfoil by calculation for various angles of incidence and flap deflection. It is shown that at all incidences this velocity distribution is a function of the position of the stagnation point, irrespective

of the flap deflection. This result is true generally, and it is suggested that use might be made of it in the design of a lift-coefficient meter, which could also be used to give warning of a stall.

THEORY OF AEROFOILS ON WHICH OCCUR BUBBLES OF STATIONARY AIR. L. C. Woods. Gt. Brit., ARC R&M 3049, 1957. 16 pp. 12 refs. BIS, New York, $0.90. Outline of a mathematical theory of the subsonic inviscid flow external to the bubble, caused by flow reattachement whose position is assumed. The influence of the bubble on the lift and moment coefficients is calculated, and some comments are made about the stalling of thin airfoils.

INITIAL LIFT OF FINITE ASPECT-RATIO WINGS DUE TO A SUDDEN CHANGE OF INCIDENCE. D. E. Lehrian. Gt. Brit., ARC R&M 3023, 1957. 6 pp. BIS, New York, $0.45. Determination of the ratio of the initial to the final values of the lift for rectangular wings and cropped delta wings of taper ratio 1/7. These values indicate that the initial lift may be greater than the final lift for aspect ratios $A \leqslant 2$. This result is confirmed by the values of instantaneous lift previously measured for the delta wing of aspect ratio 1.2 as its incidence rapidly changed.

DRAG MINIMIZATION FOR WINGS IN SUPERSONIC FLOW, WITH VARIOUS CONSTRAINTS. M. A. Heaslet and F. B. Fuller. US, NACA TN 4227, Feb., 1958. 30 pp. 13 refs. Study of the minimization of inviscid fluid drag for wings subject to constraints on lift, pitching moment, base area, or volume. An approximate solution for given lift is obtained and, for certain wing classes, analogies between lifting and nonlifting cases are found. Results are given for a family of wings with curved leading edges when lift and center of pressure at 60% chord are specified. Integrals of loading along oblique lines are presented, and minimum drag is determined for other plan forms. For nonlifting wings the occurrence of unreal shapes is discussed.

A SUBSONIC LIFTING-SURFACE THEORY FOR LOW ASPECT-RATIO WINGS. C. R. Taylor. Gt. Brit., ARC R&M 3051, 1957. 20 pp. 20 refs. BIS, New York, $1.08. Development of a method to determine the loading on low-aspect-ratio wings. The method improves on R. T. Jones's theory for wings of very small aspect ratio. Calculations have been made for 13 different wings and a comparison with other methods of solution is given for some cases.

THEORETICAL CALCULATIONS OF SUPERSONIC WAVE DRAG AT ZERO LIFT FOR A PARTICULAR STORE ARRANGEMENT. Appendix A - SUMMARY OF VELOCITY POTENTIALS FOR CANTED ARRANGEMENT. Appendix B - SUMMARY OF EQUATIONS FOR THE WAVE-DRAG COEFFICIENT OF THE CANTED ARRANGEMENT. Appendix C - SOME SPECIFIC INTEGRALS OF INTEREST OCCURRING IN THE DRAG ANALYSIS. Appendix D - SUMMARY OF FORMULAS FOR VELOCITY POTENTIALS AND WAVE DRAG FOR THE PARALLEL ARRANGEMENT. Appendix E - EXPRESSIONS FOR INTERFERENCE PRESSURES ACTING ON BASE. Kenneth Margolis, F. S. Malvestuto, Jr., and P. J. Maxie, Jr. US, NACA TN 4120, Jan., 1958. 37 pp. Analysis, based on the linearized thin-airfoil theory for supersonic speeds, for a simple two-body arrangement consisting of two wedgelike surfaces, each with a rhombic lateral cross-section and emanating from a common apex. Results for the complete range of supersonic Mach Numbers show that by orienting the axes of the bodies relative to each other a given volume may be redistributed in a manner which enables the wave drag to be reduced within the lower supersonic speed range. At higher Mach Numbers, the wave drag is always increased. Analogous drag calculations for the case of two parallel winglike bodies with the same cross-sectional shapes as the canted configuration are also included, and favorable interference pressures acting on the blunt bases of both arrangements are considered.

DESIGN OF WARPED SLENDER WINGS WITH THE ATTACHMENT LINE ALONG THE LEADING EDGE. Appendix I - SOME SPECIAL INTEGRALS. Appendix II - COMPARISON OF RESULTS OBTAINED BY SLENDER-WING THEORY, NOT-SO-SLENDER-WING THEORY AND BY LINEAR THEORY. J. Weber. Gt. Brit., RAE TN Aero. 2530, Sept., 1957. 83 pp. 15 refs. Presentation of a design method for slender warped wings with an unswept trailing edge but an otherwise arbitrary planform, which at the design lift coefficient have zero load coefficient, zero load along the leading edge, and a near planar vortex sheet from the trailing edge. The wing can have an arbitrary chordwise curvature on which a spanwise curvature is superposed in order that in any spanwise section the wing is straight over the inner part of the wing and curved over the portion near to the leading edges; the position of this change can vary arbitrarily in the chordwise direction. Formulas and working charts are given for determining the local load coefficient (and with it the streamwise velocity component), the spanwise velocity component, the total lift coefficient, and the total drag.

CONTRIBUTION OF THE WING PANELS TO THE FORCES AND MOMENTS OF SUPERSONIC WING-BODY COMBINATIONS AT COMBINED ANGLES. Appendix A - FORCES AND MOMENTS ON WING PANELS OF WING-BODY COMBINATIONS IN POTENTIAL FLOW. Appendix B - EFFECT OF BODY VORTICES ON WING-PANEL FORCES AND MOMENTS. J. R. Spahr. US, NACA TN 4146, Jan., 1958. 62 pp. Wind-tunnel investigation at a Mach Number of 1.96 and at Reynolds Numbers of 0.36 and 1.03 million to determine the normal forces, pitching moments, and rolling moments contributed by each wing panel

of a cruciform-wing and body combination over a wide range of combined angles of pitch and roll. Results show that large changes in the panel forces and moments can occur as the result of combined angles. It is found that a general theoretical method yields results in good agreement with the wind-tunnel measurements; the normal force and pitching moments contributed by the wing are essentially independent of roll angle; and the directional stability contributed by a conventional arrangement of tail surfaces on a body decreases seriously with angle of attack, especially at small sideslip angles.

VERGLEICH DER THEORETISCHEN UND EXPERIMENTELLEN WIDERSTANDSBEIWERTE IM SCHALL-UND ÜBERSCHALLGEBIET. Dietrich Fiecke. ZFW, Feb., 1958, pp. 36-47. 49 refs. In German. Comparison of drag coefficients obtained from measurements on different types of wings and bodies in sonic and supersonic flow with the corresponding values of the linearized supersonic flow theory. Various drag components are presented as an attempt to give some basic information for the estimation of the change in drag with Mach Number.

DIE WIDERSTANDSBEIWERTE VON TRAGFLÜGELN UND RÜMPFEN NACH DER LINEAREN ÜBERSCHALLTHEORIE. F. Wegener and F. Kowalke. ZFW, Feb., 1958, pp. 29-35. In German. Determination of the wave drag at zero lift for wings and bodies, using the linearized supersonic-flow theory. The drag component is estimated for the wing alone as well as for the wing-tail arrangement. Infinite and finite span airfoils, as well as spheroidal fusilages are examined.

WINDKANALERGEBNISSE ZUM INTERFERENZPROBLEM MODERNER HOCHLEISTUNGSFLUGZEUGE. Xaver Hafer. ZFW, Jan., 1958, pp. 20-28. In German. Presentation of wind-tunnel results concerning the interference problem of modern high-performance aircraft. The best wing-body-tail-combination in incompressible flow for obtaining satisfactory flight characteristics is investigated, and possible improvements due to boundary-layer and ground effects are discussed.

AEROELASTICITY

AEROELASTIC INSTABILITY AT HIGH MACH NUMBER. J. P. Chawla. J. Aero. Sci., Apr., 1958, pp. 246-258. 13 refs. USAF-sponsored discussion of the limitations of the piston theory, and derivation of the aerodynamic forces on oscillating airfoils in a slightly different form to conform to the NACA practice, using Lighthill's approach. The familiar nondimensional flutter coefficients are tabulated for general double and single wedge and parabolic biconvex profiles. Extensive parametric studies are made for preliminary design to aid in estimating the effect on flutter speed and frequency of airfoil thickness and profile, initial angle of attack, modal shape, changes in elastic and inertial properties of the wing, and flight altitude.

TABLES OF AERODYNAMIC FLUTTER DERIVATIVES FOR THIN WINGS AND CONTROL SURFACES IN TWO-DIMENSIONAL SUPERSONIC FLOW. I. T. Minhinnick and D. L. Woodcock. Gt. Brit., RAE Rep. Struc. 228, Oct., 1957. 44 pp. Presentation of values giving the forces on wings and control surfaces due to wing motion for control surface/wing chord ratios of 0(0.1), 0.6, and 1.0, and for at least eleven values of the frequency parameter between 0 and 1.5., as well as for different Mach Numbers.

EFFECTS OF AIRPLANE FLEXIBILITY ON WING STRAINS IN ROUGH AIR AT 35,000 FEET AS DETERMINED BY A FLIGHT INVESTIGATION OF A LARGE SWEPT-WING AIRPLANE. R. H. Rhyne. US, NACA TN 4198, Jan., 1958. 23 pp. Experimental investigation on a large bomber airplane, and comparison of results with data previously obtained at low altitude (5,000 feet). The effects of wing flexibility on the wing strain are, on the average, about 20% larger at higher altitude. Representative values of the amplification factors vary from about 1.3 at the root stations to about 2.5 at the midspan stations.

MEASURED AND PREDICTED DYNAMIC RESPONSE CHARACTERISTICS OF A FLEXIBLE AIRPLANE TO ELEVATOR CONTROL OVER A FREQUENCY RANGE INCLUDING THREE STRUCTURAL MODES. Appendix A, B - CALCULATION OF FREE-FREE MODES. Appendix C - DERIVATION OF EQUATIONS OF MOTION. H. A. Cole, Jr., and E. C. Holleman. US, NACA TN 4147, Feb., 1958. 81 pp. 14 refs. Experimental investigation over an operating Mach Number range at altitudes from 15,000 to 35,000 feet. Response quantities for the nose, center of gravity, wing tip, and tail are shown for frequencies from the aircraft short-period mode to the fuselage first-bending mode. Comparisons are made between the measured responses and those predicted by dynamic analyses with up to three structural degrees of freedom. Dynamic response measured in flight is interpreted in terms of lines of low response, and comparisons are made with predicted lines of low response and node lines predicted by free-free analysis and measured in ground vibration tests.

CONCEPT OF COMPLEX STIFFNESS APPLIED TO PROBLEMS OF OSCILLATIONS WITH VISCOUS AND HYSTERETIC DAMPING. Appendix - DETAILS OF CALCULATING THE ENERGY DISSIPATION IN AN EXPONENTIALLY DECAYING HARMONIC OSCILLATION. S. Neumark. Gt. Brit., RAE Rep. Aero. 2592, Sept., 1957. 45 pp. 21 refs. Theoretical investigation of the concept of complex stiffness in problems of oscillations which shows that the correct expressions for complex stiffness are different in the cases of forced and free oscillations. All fundamental cases for a single degree of freedom are critically re-examined and compared, and fallacious solutions are eliminated.

XUM

LIFT AND MOMENT ON THIN ARROWHEAD WINGS WITH SUPERSONIC EDGES OSCILLATING IN SYMMETRIC FLAPPING AND ROLL AND APPLICATION TO THE FLUTTER OF AN ALL-MOVABLE CONTROL SURFACE. Appendix A - DEVELOPMENT OF VELOCITY POTENTIAL. Appendix B - FORCE AND MOMENT COEFFICIENTS. Appendix C - NUMERICAL EXAMPLE OF A FLUTTER CALCULATION. H. J. Cunningham. US, NACA TN 4189, Jan., 1958. 58 pp. Application of a method based on linearized supersonic potential-flow theory to the cases of symmetric flapping and rolling oscillations in order to obtain section lift and moment plus total unsteady lift and moment coefficients. Spanwise distributions are illustrated and compared with results of a strip-theory method. The aerodynamic coefficients are applied to a couple-mode flutter analysis of an all-movable control surface for which the flexibilities are concentrated in a supporting shaft.

A METHOD FOR THE CALCULATION OF THE LATERAL RESPONSE OF AIRPLANES TO RANDOM TURBULENCE. Appendix A - FREQUENCY-DEPENDENT STABILITY DERIVATIVES DUE TO SIDE GUSTS. Appendix B - AIRFRAME TRANSFER FUNCTIONS. Appendix C - TWO EQUIVALENT WAYS OF EXPRESSING THE POWER SPECTRAL RELATIONSHIP BETWEEN GUSTS AND AIRPLANE MOTIONS. J. M. Eggleston and W. H. Phillips. US, NACA TN 4196, Feb., 1958. 34 pp. Presentation of the procedure in which the gust velocities are represented as rolling gusts, yawing gusts, and side gusts. Random distributions of gust velocities across the span are taken into account in defining the rolling and yawing gusts. Complex stability derivatives are used to account for the random distribution of side gusts along the fuselage and vertical tail and the lag effects in gust penetration. A sample calculation procedure is presented for obtaining the response of the airplane in each degree of freedom.

AVIATION MEDICINE

EIN GERÄT ZUR FORTLAUFENDEN ELEKTRISCHEN IMPULSFREQUENZANALYSE UND -INTEGRATION. H. Brüner and K. Dietmann. DVL Bericht No. 53, Dec., 1957. 14 pp. 14 refs. Westdeutscher Verlag, Köln & Opladen. In German. Description of an apparatus for the continuous electrical analysis and integration of impulse frequencies used on subjects under stress and anoxia. The equipment is designed to operate over a wide range of environmental conditions, i.e., pressure chambers, climatic chambers, etc. The impulses observed are transformed into electrical pulses and superposed on a rectified current wave form; the modified trace is recorded on the usual type of recorder, providing amplitude and frequency; it is channeled into two separate stages giving a trace for integration of the impulse and a trace for frequency analysis, respectively.

COMPUTERS

THE METHOD OF CHARACTERISTICS FOR ROUTINE ELECTRONIC COMPUTER CALCULATION. R. D. Linnell. Convair Sci. Res. Lab. RN 3, Apr., 1957. 38 pp. Development of a high speed electronic computer program for routine calculation of supersonic flow about bodies of revolution by the method of characteristics. The equations to be solved numerically for plane and axial symmetric flow problems with or without rotation are given, and the computer logic and address system necessary for general bodies are included. The body-of-revolution problem is used to illustrate the procedure which can be used for nozzles, jets, airfoils, and inlets.

ÜBER DIE PRAKTISCHE DURCHFÜHRUNG VON RECHNERISCHEN FLATTERUNTERSUCHUNGEN. Helmut Falkenheiner. ZFW, Feb., 1958, pp. 52-57. In German. Presentation of a block diagram showing the computational procedure involved in the study of the flutter behaviour of an aircraft. It is assumed that this investigation started at an early design stage and therefore can only be based on general arrangement drawings and calculated data. The assumptions are eventually checked by model tests. Using the matrix form for the equations, computation rules are given for the matrices of the actual flutter equations, in particular for the mass, stiffness, and unsteady aerodynamic terms. It is concluded that it is advisable to change the order of the matrices through the different investigation stages so as to achieve a compromise between desired accuracy and tolerable computation effort.

ELECTRONICS

ON THE THEORY OF ANISOTROPIC OBSTACLES IN CAVITIES. Walter Hauser. Quart. J. Mech. & Appl. Math., Feb., 1958, pp. 112-118. USAF-Army-Navy-supported derivation of variational expressions for the resonant frequencies of a cavity containing a material with tensor electromagnetic properties. The relationship of the variational expressions to the Bethe-Schwinger perturbation formula is shown and the advantage over it is discussed.

FUELS & LUBRICANTS

FRICTION STUDIES OF VARIOUS MATERIALS IN LIQUID NITROGEN. D. W. Wisander, W. F. Hady, and R. L. Johnson. US, NACA TN 4211, Feb., 1958. 35 pp. 20 refs. Experimental investigation at a sliding velocity of 2,300 feet per minute and a load of 1,000 grams using a hemisphere (3/16-in. radius) sliding on the flat surface of a rotating disc. Carbon, phenolic laminates, and graphite-filled Teflon are run against metals. Results show that Teflon gives lower friction coefficients (0.15) and wear than any of the other materials studied, including rolling-contact-bearing

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metals, mechanical-seal-type carbons, phenolic laminates, and a cermet. Other filled Teflon compositions give good results.

ICE FORMATION & PREVENTION

AERODYNAMIC EFFECTS CAUSED BY ICING OF AN UNSWEPT NACA 65A004 AIRFOIL. Appendix - EFFECT OF FLOW SEPARATION ON AERODYNAMIC CHARACTERISTICS OF AIRFOIL. V. H. Gray and U. H. von Glahn. US, NACA TN 4155, Feb., 1958. 47 pp. 12 refs. Experimental investigation showing that the magnitude of the aerodynamic penalties is primarily a function of the shape and size of the ice formation near the airfoil leading edge. The exact size and shape of the ice formations are determined photographically and it is found that they are complex functions of the operating and icing conditions. At angles of attack less than 4^{o} both rime and glaze-ice formations increase drag and reduce lift and diving moments. At angles of attack greater than 4^{o}, drag coefficients increase with glaze-ice formations and decrease with rime ice; lift coefficients generally increase with glaze ice and are variably affected by rime ice; pitching-moment changes are rather erratic and depend on the ice shape. When the airfoil is iced at high angles of attack and rotated to lower angles, large negative pitching moments are obtained. Ice formations on the airfoil have no significant effects on control surface hinge moments.

MISSILES

HISTORY OF GERMAN GUIDED MISSILES DEVELOPMENT. (NATO AGARD First Guided Missiles Seminar, Munich, Apr., 1956.) NATO AGARDograph 20, 1957. Edited by Th. Benecke and A. W. Quick. Published for and on behalf of AGARD, NATO, by the Wissenschaftliche Gesellschaft für Luftfahrt e.V. Braunschweig, Verlag E. Appelhans & Co., 1957. 419 pp. $7.50; 55 s.; 32 DM. The present AGARDograph contains the papers of the Munich Symposium which surveyed the extensive research and development work carried out in Germany prior to 1945. Illustrations and discussion are included. Partial Contents: Summary of German Developments in Guided Missiles, Th. Benecke. Contributions to the Guidance of Missiles, E. Fischel. Spoiler Control of Missiles, G. Ernst. Guided Missiles Radio Remote Control, J. Dantscher. Further Development of Remote Control Systems and the Remote Control of Air-to-Air Missiles, J. Dantscher. Summary of the Development of High-Frequency Homing Devices, G. Güllner. Guidance of Surface-Air Missiles by Means of Radar, K. H. Schirrmacher. The Physical and Technical Development of Infrared Homing Devices, E. W. Kutzscher. Some Special Problems of Power Plants, O. Lutz. The Design and Development of the Solid-Fuel Rocket and its Performance, H. Vüllers. Development of Hydrogen Peroxide Rockets in Germany, H. Walter. The Development of the V-2 Rocket Engine, M. Schilling.

UNA FORMULA ELOQUENTE DELLA MISSILISTICA. Pietro Formentini. Riv. Aero., Jan., 1958, pp. 13-24. In Italian. Analysis of the mechanics of missiles covering: basic laws, escape velocity, orbital velocity of an artificial satellite, specific impulse and specific power, characteristic velocity and synergic efficiency, as well as the objectives and problems of spacial missiles.

VERTICAL RE-ENTRY OF VERY LIGHT-WEIGHT BODIES INTO THE EARTH'S ATMOSPHERE. R. D. Linnell. Convair Sci. Res. Lab. RN 9, Oct., 1957. 30 pp. Determination of the body velocity using rough approximations, an analytical method, and numerical integration. It is found that the maximum deceleration increases linearly with increasing release altitude and occurs at altitudes around 250,000 feet. Appreciable decelerations occur even for release altitudes of the order of 10^{6} feet. It is further found that the temperature of the thin external surfaces of light-weight bodies increases rapidly when the release altitude is increased. Extra material may be required locally in the detailed design in order to reduce the surface temperature.

HYPERSONIC FLIGHT AND THE RE-ENTRY PROBLEM (THE TWENTY-FIRST WRIGHT BROTHERS LECTURE). H. J. Allen. J. Aero. Sci., Apr., 1958, pp. 217-227; Discussion, pp. 228, 229, 262. 19 refs. Investigation of three long-range, high-speed rocket vehicles - the ballistic, glide, and skip rocket - and comparison of their optimum performance with one another as well as that of a typical supersonic airplane powered by air-breathing engines. The ratio of initial to final ("empty") weight as well as the ratio of final weight to payload are discussed, and the relative flight efficiency is estimated. Aerodynamic heating is investigated from a general point of view as well as its relation to the four rocket types, the aerodynamic loads, and stability. It is concluded that the ballistic vehicle compares very favorably with the supersonic airplane for long range as well as short range flight, and that the glide rocket may also prove to be attractive, but not so the skip rocket, due to its severe coolant requirements. New problems of hypersonic vehicles are also considered.

A NOTE ON GODDARD'S PROBLEM. G. Leitmann. Astronautica Acta, Fasc. 4, 1957, pp. 237-240. Investigation showing that it is necessary to take into account the variation of burning time for "neighboring" trajectories, when considering the classical problem of minimizing the initial mass of a rocket required to reach specified altitude and velocity.

NAVIGATION

ANALYSIS OF AN INERTIAL GUIDANCE SYSTEM. D. B. Duncan. Jet Propulsion, Feb., 1958, pp. 111-116. Description of the characteristics of the system for a simplified guidance problem, e.g., navigation on a spherical nonrotating body. Error equations relating component performance to guid-

ance accuracy are derived, exhibiting 84 min. period oscillations which typify inertial systems.

POWER PLANTS

PROPULSION SYSTEMS FOR SPACE FLIGHT. R. B. Dillaway. (IAS 26th Annual Meeting, New York, Jan. 27-30, 1958.) Aero. Eng. Rev., Apr., 1958, pp. 42--49, 52. 22 refs. Theoretical investigation of possible space power plants with consideration of chemical, nuclear, and ion rocket systems. Typical engine configurations are examined as well as the design requirements imposed on these propulsion systems by the peculiarity of the environment and the mission for which they are intended. Differences and obvious parallels between the different systems are brought out, and it is concluded that all systems discussed can, with suitable effort, probably be used to pursue the space mission considered.

RELATIVISTIC TREATMENT OF ROCKET KINEMATICS AND PROPULSION. P. F. von Handel and Herbert Knothe. USAF MDC TR 58-3 [AD 135004], Jan., 1958. 83 pp. Mathematical investigation of general kinematics and the propulsion of space vehicles within the framework of the special theory of relativity. The reception and expulsion of particles and photons by a space vehicle as well as their kinematic effects are examined in detail. The optimization of the final velocity of the vehicle is determined as a parametric function of the available energy and of the final mass (pay load). Illustrative numerical examples are presented, and it is concluded that it will not be possible to fly a vehicle into galactic space, the flight being restricted to the planetary space, due to basic physical laws.

Jet & Turbine

THEORETICAL ANALYSIS OF TOTAL-PRESSURE LOSS AND AIRFLOW DISTRIBUTION FOR TUBULAR TURBOJET COMBUSTORS WITH CONSTANT ANNULUS AND LINER CROSS-SECTIONAL AREAS. Appendix A, B - INCOMPRESSIBLE-FLOW CALCULATIONS FOR TUBULAR TURBOJET COMBUSTOR WITH CONSTANT ANNULUS AND LINER CROSS-SECTIONAL AREAS. Appendix C - COMPRESSIBLE-FLOW CALCULATIONS FOR TUBULAR TURBOJET COMBUSTOR WITH CONSTANT ANNULUS AND LINER CROSS-SECTIONAL AREAS. Ch. C. Graves and J. S. Grobman. US, NACA RM E56I04, Jan. 4, 1957. 85 pp. 14 refs. Graphical presentation of data in terms of the following parameters: (1) combustor reference Mach Number, (2) ratio of combustor-exit-to-inlet total temperature, (3) fraction of total airflow passing through the liner dome, (4) $A_{h,T}/A_r$, and (5) A_L/A_r, where $A_{h,T}$ is the total liner open hole area and A_L and A_r are the liner and combustor total cross-sectional areas, respectively. The calculations include the effects of heat release, annulus wall friction, and variation in discharge coefficients of the liner wall openings along the combustor.

SELF-EXCITED VIBRATION OF AXIAL-FLOW COMPRESSOR BLADES. Appendix I - DERIVATION OF EXPRESSIONS FOR CRITICAL VELOCITIES. Appendix II - INTERPRETATION OF DESIGN RULE. A. D. S. Carter and D. A. Kilpatrick. (IME General Meeting, London, Dec. 7, 1956.) IME Proc., No. 7, 1957, pp. 245-262; Discussion, pp. 262-277; Author's Reply, pp. 278-281. 10 refs. Experimental investigation of the phenomenon, supplemented by a simple theoretical correlation attempt, as well as by single-stage work and by multi-stage full-scale tests. Both flutter and stall cell excitation are encountered and described. A semiempirical design rule is suggested, and its interpretation in terms of the normal blade design parameters is included.

Rocket

ÜBER FESTSTOFFRAKETEN. Ernst Mohr. (Deutsche Arbeitsgem. Racketentech. 5th Annual Meeting, Oldenburg, Sept. 28, 1957.) Weltraumfahrt, Dec., 1957, pp. 111-116. In German. Outline of the principles of charge construction, presentation of data for calorific values and thrust of some conventional propellants, and description of the thrust-producing mechanism in a typical rocket configuration. Includes description of a two-stage, spin-stabilized meteorological sounding rocket as an example of solid propellant application and outline of a project for the construction of an 11-stage solid-propellant satellite rocket.

ANALYSIS OF REGENERATIVE COOLING IN ROCKET THRUST CHAMBERS. L. E. Dean and L. A. Shurley. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, Feb., 1958, pp. 104-110. Discussion of the experimentally determined heat-transfer data obtained on JP-4 and RFNA under conditions simulating those which occur during thrust chamber operation. An electrical analogy technique is used to determine the temperature and heat flux distribution because of the irregular shape of coolant passages. Using the experimental data for film coefficients and a two-dimensional electrical analog, the heat flux and temperature distribution within the walls of a tubular chamber cooled with JP-4 and within the walls of a drilled passage thrust chamber cooled with RFNA are obtained.

PRODUCTION

Metalworking

MECHANICS OF ADHESIVE JOINTS. I - RESIDUAL STRESSES. II - STRESS DISTRIBUTION IN ADHESIVE LAYER UNDER TENSILE LOADING. Yonosuke Kobatake and Yukihiko Inoue. Appl. Sci. Res., Sect. A, Nos. 1; 2-3, 1957; 1958, pp. 53-64; 100-108. Analysis of the thermal stress as representative residual stress which occurs during glueing operations. Reducing the problem of the thermal stress to one of boundary traction, the stress function of a rectangular plate with two parallel opposite edges glued to two rigid planes, re-

spectively, is solved and verified photoelastically. It is found that the disorderliness of stress distribution near the free edge, due to constrained contraction, suddenly fades within a short distance from the edge, and beyond this region the stress distribution becomes rather normal.

SAFETY

ACCELERATIONS IN TRANSPORT-AIRPLANE CRASHES. Appendix - VARIATION OF CRASH-IMPACT FORCES NORMAL TO LONGITUDINAL AXIS WITH ANGLE OF IMPACT. G. M. Preston and G. J. Pesman. US, NACA TN 4158, Feb., 1958. 76 pp. Experimental investigation with full-scale aircraft for the determination of the crash loads that result from a variety of crash events. It is shown that pressurized transport airplanes can withstand high-impact-angle crashes and still maintain survivable areas within the fuselage. During unflared-landing crashes greater fuselage crashing occurred with high-wing than with low-wing aircraft. Normal accelerations exceeding human tolerance occur in crashes in which modest fuselage damage occurs. Within the structural range represented by the airplanes crashed, the configuration of the airplane has little effect on normal acceleration.

SPACE TRAVEL

COMMUNICATIONS AND NAVIGATION TECHNIQUES OF INTERPLANETARY TRAVEL. P. A. Castruccio. IRE Trans., ANE Ser., Dec., 1957, pp. 216-223. Discussion of the following problems: navigation techniques involving the determination of the ship's position and direction of travel, ship-to base, and ship-to-ship communications as well as anticollision means. Specially considered is the problem of increasing the communication range.

EFFECT OF AIR DRAG ON ELLIPTIC SATELLITE ORBITS. R. E. Roberson. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, Feb., 1958, pp. 90-96. Determination of simple approximate expressions for the decay of eccentricity with radius, the decay of radius with true anomaly, and the growth of true anomaly with time, using the parameters variation and the Krylov-Bogoliuboff approximation. The special case of spiral orbits and the effect of asphericity and rotation of the earth's atmospheric shell are discussed.

THE EFFECT OF THE EARTH'S OBLATENESS ON THE ORBIT OF A NEAR SATELLITE. Appendix - SOLUTION OF THE EQUATIONS OF MOTION OF A SATELLITE OVER OBLATE EARTH IN VACUO, FOR ORBITS OF SMALL ECCENTRICITY. D. G. King-Hele and D. M. C. Gilmore. Gt. Brit., RAE TN G.W.475, Oct., 1957. 67 pp. 15 refs. Presentation of analytical solutions for the equations of motion of a satellite in an orbit over an oblate earth vacuum, obtained by a perturbation method. It is shown that the earth's oblateness has four main effects on the motion: the orbital plane rotates, instead of remaining fixed about the earth's axis, in the opposite sense to the satellite, at a rate of about 8 cos α degrees per day, where α is the inclination of the orbital plane to the equatorial plane; the period of revolution of the satellite is greater for an inclined orbit, the radial distance r from the earth's center changes, and the major axis of the orbit rotates in the orbital plane at a rate of about $4(5\cos^2\alpha - 1)$ degrees per day.

ON DETERMINING THE ORIENTATION OF A CYLINDRICAL ARTIFICIAL EARTH-SATELLITE. R. J. Davis, R. C. Wells, and F. L. Whipple. Astronautica Acta, Fasc. 4, 1957, pp. 231-236. Presentation of a method for determining the satellite orientation, assuming that it is tumbling very slowly, one half of its surface being a diffuse and the other half a specular reflector. The procedure consists in observing the flash from the specularly reflecting surface and is based on purely geometrical considerations, neglecting diffraction, deterioration of the specular surface, and atmospheric absorption and diffraction.

STRUCTURES

PEWNA METODA OBLICZANIA KONSTRUKCJI SEGMENTOWYCH STATYCZNIE NIEWYZNACZALNYCH. Stanislaw Lukasiewicz. Arch. Budowy Maszyn, No. 4, 1957, pp. 427-457. In Polish, with summaries in English and Russian. Discussion of a method for calculating statically indeterminable segmented constructions without being forced to solve a system of differential equations. The method permits the evaluation of internal forces, both for infinitely rigid and flexible transverse elements. Statically indeterminable forces in a construction consisting of identical segments are defined and presented in the form of a finite formula.

Cylinders & Shells

SYMMETRIC BENDING OF SHALLOW SHELLS OF REVOLUTION. Eric Reissner. J. Math. & Mech., Mar., 1958, pp. 121-140. ONR-supported analysis which assumes a more general system of stress-strain relations than is usually done in shell theory, and the reduction of this system to two second-order nonlinear differential equations. Two problems are considered, the first being the edge effect in shallow shells subject to internal pressure, and the second being the effect of uniform surface pressure in accordance with linear theory with the assumption of different elastic behavior in meridional and circumferential direction. Explicit results are obtained in the latter case for two classes of orthotropic stiffness assumptions for which the differential equations of the problem can be solved in terms of Bessel functions.

CREEP BUCKLING OF CYLINDRICAL SHELLS. Erik Sundström. Acta Polytechnica, No. 5 (230),

1957. 31 pp. Determination of the critical buckling time of a cylindrical shell made of a material obeying the Norton creep formula and subjected to external pressure. Nonlinear power laws are assumed to hold for primary and secondary creep, and the effect of axial forces is included. Conditions at the center part of the shell are shown to determine the lifetime, whereas end conditions have little influence. A trigonometric series is assumed for the deflection, and diagrams and tables of the stress distribution and lifetime are given.

PROPAGATION OF NONAXIALLY SYMMETRIC WAVES IN ELASTIC CYLINDRIGAL SHELLS. R. M. Cooper and P. M. Naghdi. ASA J., Dec., 1957, pp. 1,365-1,373. 13 refs. ONR-sponsored prediction of phase velocities and amplitude ratios for nonaxially symmetric as well as purely torsional propagation of elastic waves, using previously derived equations of motion. The predictions of the two systems of equations are compared and the conclusions specified.

SOME CHARACTERISTICS OF THE FLEXURAL VIBRATIONS OF ORTHOGONALLY STIFFENED CYLINDRICAL SHELLS. W. H. Hoppmann II. ASA J., Jan., 1958, pp. 77-82. 10 refs. Review of a theoretical study of shells, and presentation of frequency equations and of an experimental method for verifying the theory. Experimental frequencies for an isotropic shell as well as two different designs of orthogonally stiffened shells are given in tables, and the experimental and corresponding theoretical results are discussed. It is shown that a peculiar dip in the frequency spectrum discovered by Arnold and Warburton for uniform isotropic shells exists theoretically, and it is verified for stiffened shells. It is further shown that there is a bias in the excitability of the modes of vibration, as determined experimentally.

Elasticity & Plasticity

HYPO-ELASTIC POTENTIALS. J. L. Ericksen. Quart. J. Mech. & Appl. Math., Feb., 1958, pp. 67-72. 15 refs. Derivation of conditions necessary and sufficient for a scalar potential of some hypo-elastic materials which is analogous to the elastic potential or strain energy function of the elasticity theory.

ON THE PHENOMENA OF CRACK FORMATION AND PROPAGATION. W. Olszak. Acad. Pol. Sci. Bul., No. 6, 1957, pp. 377-387. 12 refs. Study of the elastic and plastic stress variations in the neighborhood of a crack, using two methods: the first is based on the assumption of the elasticity theory, introducing appropriate strength criteria, the second considers the problem as a problem of plasticity. These considerations are generalized to elastically and plastically nonhomogeneous bodies. A crack theory is developed explaining fairly well certain phenomena observed during crack experiments and enabling an approximate prediction of crack formation and propagation mechanisms to be formulated.

NIEKTÓRE ZAGADNIENIA TEORII OBCIĄGANIA POWŁOK CYLINDRYCZNYCH. Wojciech Szczepiński. Arch. Budowy Maszyn, No. 4, 1957, pp. 459-479. In Polish, with summaries in English and Russian. Discussion of some problems in the theory of stretch-forming of sheets. The stress-distribution problem is solved using the equations of balance or the plasticity condition. As a boundary condition the tangent and normal stresses on the external contour equal to zero are considered. The solution for a cylindrical strech-forming is given first. It is shown that if the sheet thickness is less than 0.1 R (R = curvature radius of the tool-body) the values of the sheet pressure can be calculated approximately. The problem is also solved for some other cases in which a solution can be obtained in a closed form.

Plates

THE PROBLEM OF LARGE DEFLECTIONS OF ORTHOTROPIC PLATES. Tadeusz Iwiński and Jerzy Nowiński. Arch. Mech. Stosowanej, No. 5, 1957, pp. 593-603. Extension of Berger's method for isotropic plates to the calculation of the deflection of orthotropic plates. Previously obtained solutions for a circular plate uniformly loaded are compared for the particular value k = 1/3 of the coefficient of orthotropy with another approximate solution obtained during the present investigation by means of the pseudo-energy equation. The two solutions prove to be relatively near each other; however, using for comparison the accuracy obtained by Berger for an isotropic plate, the solution obtained by rejecting the middle plane e_2 is probably more accurate.

MIXED BOUNDARY VALUE PROBLEMS FOR RECTILINEAR [Multilateral] PLATES. G. A. Mariboli. Arch. Mech. Stosowanej, No. 5, 1957, pp. 507-524. Theoretical investigation of triangular plates with the following type of mixed condition: one edge (wholly or partly) clamped and the other two simply supported. The solution is represented in an integral form by superposition of two systems: (a) a basic system, i.e., a plate under uniform load with all edges simply supported and (b) a system with clamping taken into account. It is shown that the moment at the clamped edge occurs as the unknown quantity in the integrand and is obtained from the boundary condition at the clamped part.

CHARTS RELATING THE COMPRESSIVE AND SHEAR BUCKLING STRESSES OF LONGITUDINALLY SUPPORTED PLATES TO THE EFFECTIVE DEFLECTIONAL STIFFNESS OF THE SUPPORTS. A. E. Johnson, Jr. US, NACA TN 4188, Feb., 1958. 42 pp. Analysis of the stability of long flat rectangular plates assuming simply supported plate edges as well as plates supported along one or two intermediate longitudinal lines by lines of deflectional springs (elastic line supports). The results are presented in the form of charts useful in the determination of the buckling load of plates stiffened by stringers or webs.

Thermal Stress

TWO STEADY-STATE THERMOELASTIC PROBLEMS. Witold Nowacki. Arch. Mech. Stosowanej, No. 5, 1957, pp. 579-592. Determination of the state of stress in an elastic space and semispace due to a temperature field. The difference between the two problems considered is that of thermal boundary conditions in the z = 0 plane. The solution obtained for the elastic space serves for the construction of the more complex problem — that of determining the stress state in the elastic semispace free from stress in the z = 0 plane.

STAN NAPRĘŻEŃ WYWOLANY W PÓLPRZESTRZENI SPRĘŻYSTEJ DZIAŁANIEM CHWILOWEGO ŹRÓDŁA CIEPŁA. Witold Nowacki. Arch. Budowy Maszyn, No. 4, 1957, pp. 413-425. In Polish, with summaries in English and Russian. Study of the stress distribution in an elastic half-space caused by an instantaneous heat source in the plane bounding the elastic half-space. The problem is considered as a quasistatic one, and the stress distribution in the elastic half-space thermally insulated in the bounding plane as well as in the case of a constant temperature T = 0 (in the plane) is taken into account. The stress distribution of an unbounded elastic space is determined using the potential of the thermoelastic displacement connected with the temperature field, and its final components are obtained by means of Loves's function. It is shown that these components satisfy any boundary condition in the plane z = 0.

SOME EFFECTS OF KINETIC HEATING ON THE STIFFNESS OF THIN WINGS. II. S. L. Kochanski and J. H. Argyris. Aircraft Eng., Feb., 1958, pp. 32-40. Investigation of the effects of large spanwise curvature and rate of twist on the distortion of the cross section when thermal stresses are present. The moment-curvature and the torque-rate of nonlinear twist relationships are established, and it is shown that large deformations give rise to a pronounced coupling between twisting and bending modes. Also derived are the practically important instantaneous (tangent) and overall (secant) stiffnesses, both for bending and torsion. Two cross sections are analyzed in detail: the uniform flat plate and the symmetrical double wedge. For the flat plate an exact theory is given. The double-wedge investigation is only approximate but it is sufficiently accurate for engineering purposes. A number of graphs illustrate the main results of the analysis.

THE EFFECTS OF KINETIC HEATING ON AIRCRAFT STRUCTURES. A. W. Kitchenside. RAeS J., Feb., 1958, pp. 105-117. 33 refs. Discussion on the generation of heat within the boundary layer, together with the fundamentals of heat transfer to and within the structure. The effects of temperature and temperature gradient upon the structure are then analyzed. Some methods for alleviating the problems introduced are reviewed, and finally design requirements are considered.

THERMODYNAMICS

Combustion

MEASUREMENT OF DETONATION INDUCTION DISTANCES IN HYDROGEN-OXYGEN AND ACETYLENE-OXIGEN-NITROGEN MIXTURES AT NORMAL AND ELEVATED INITIAL PRESSURES AND TEMPERATURES. L. E. Bollinger and Rudolph Edse. USAF WADC TR 57-414 [AD 130874], June, 1957. 88 pp. 10 refs. Experimental investigation which indicates that predetonation length decreases with increasing initial pressure for all fuel concentrations investigated. The induction distance is reduced from 61 cm. at one atmos. to five cm. at 25 atmos., for a 60% fuel mixture when the initial temperature is 100°F. Increasing the initial temperature 200°C. lengthens the distance required to establish a detonation. However, at 10 atmos. pressure the induction distance is practically independent of initial temperature for fuel concentrations between 50% and stoichimetric proportions.

Heat Transfer

THE EFFECT OF A VERTICAL LAPSE RATE OF TEMPERATURE ON THE SPIRAL FLOW OF A FLUID IN A HEATED ROTATING CYLINDER. G. N. Lance. J. Fluid Mech., Feb., 1958, pp. 523-530. Theoretical investigation of a viscous fluid contained in a rotating cylinder heated from below. Previous work had assumed that the convective terms in the heat transfer equation were negligible, but in the present treatment one of the convective terms is included. The results confirm the physical reasoning that, when a lapse rate is positive, the stability is increased and the motion is therefore decreased.

WIND TUNNELS & RESEARCH FACILITIES

FLOW IN SHOCK TUBES WITH AREA CHANGE AT THE DIAPHRAGM SECTION. R. A. Alpher and D. R. White. J. Fluid Mech., Feb., 1958, pp. 457-470. 13 refs. Theoretical and experimental studies of the effects on shock tube flows of a monotonic convergence at the diaphragm section. Systematic flow equations are developed for tubes having either a monotonic convergence or a convergence-divergence in the diagraphragm section. Except across the shock front itself, isentropic processes and ideal gas behavior have been assumed. Simplified procedures are presented for predicting the ideal-flow parameters over a wide range of operating conditions, as well as for comparing straight and convergent tubes. Such comparisons made by other investigators are found to be incomplete or in error. The experiments described utilize a very simple device for altering the diaphragm section convergence and for multistation measurement of shock velocity. The expected effect of convergence is verified over a wide range of Mach Numbers.

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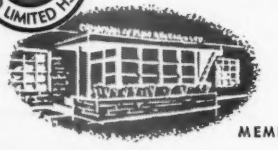

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coefficients in the study covering stability of undisturbed motions of a dynamic system.

O Flattere Tailindricheskikh Obolochek i Panelei, Dvizhushchikhsia v Potoke Gaza. R. D. Stepanov. *Prikl. Mat. i Mekh.*, Sept.-Oct., 1957, pp. 644–657. In Russian. Investigation of flutter of cylindrical shells and panels moving in a gas stream. The equations of shells are assumed in the form of the general Vlasov theory. Aerodynamic forces acting on the shell are taken into account only as forces of the excessive pressure according to Iliushin's formula.

Ustoichivost' Lopatki, Dvizhushcheisia v Gaze. A. A. Movchan. *Prikl. Mat. i Mekh.*, Sept.-Oct., 1957, pp. 700–706. In Russian. Investigation of the stability of a thin rectangular panel of constant thickness with two simply supported and two free edges moving in a gas at high supersonic speeds.

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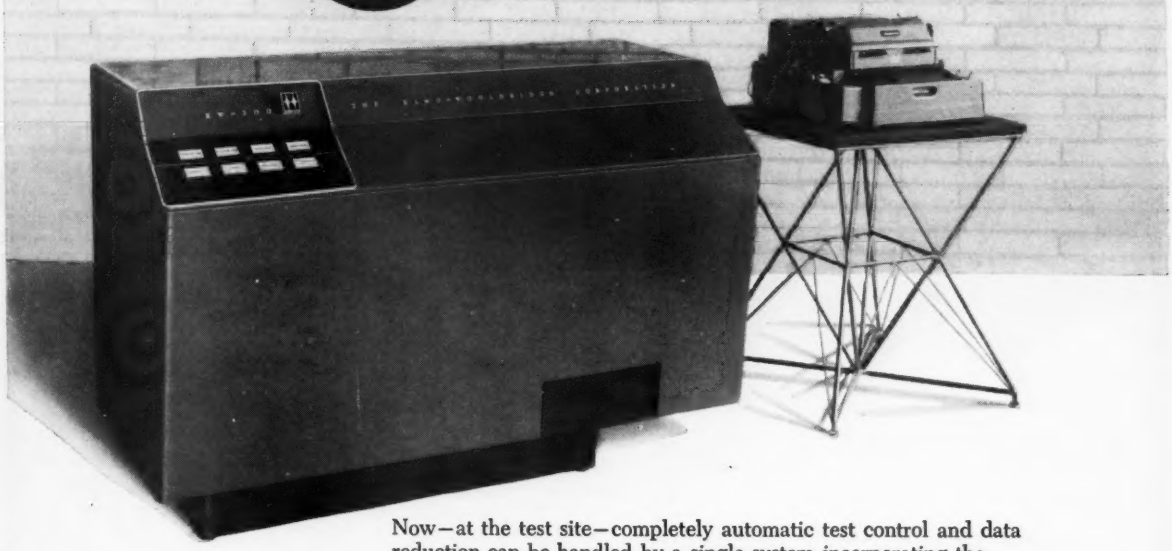

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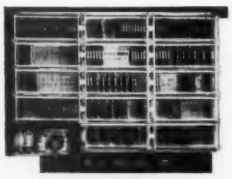

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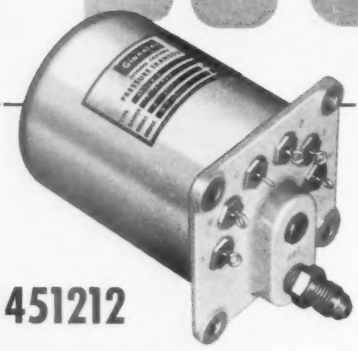

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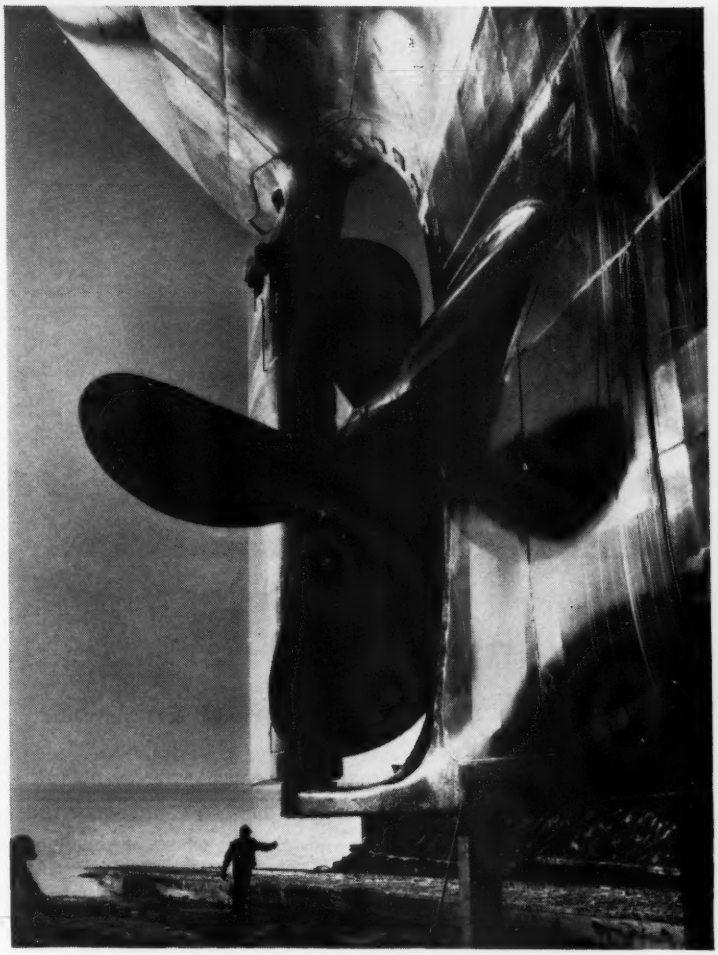

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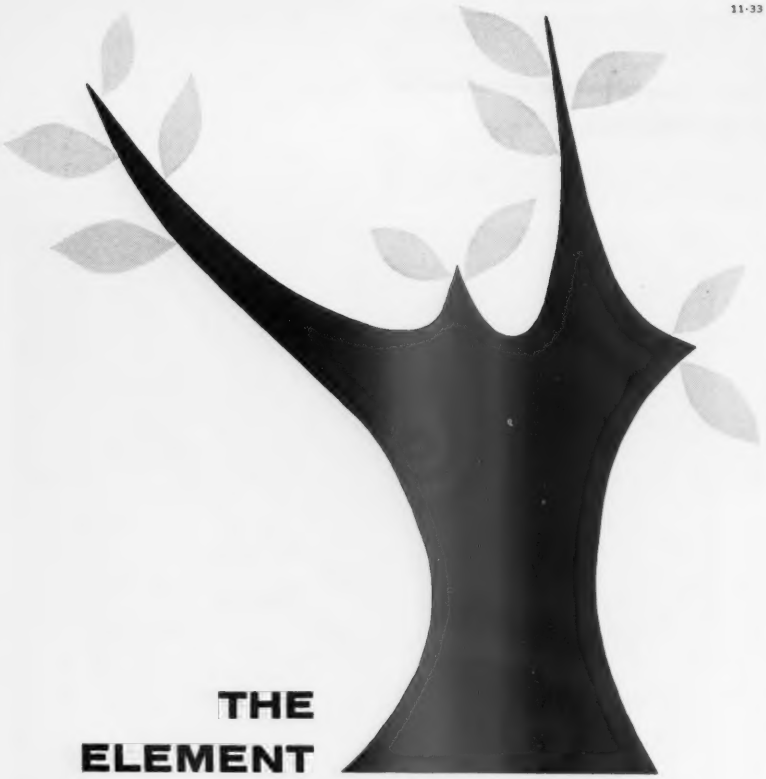

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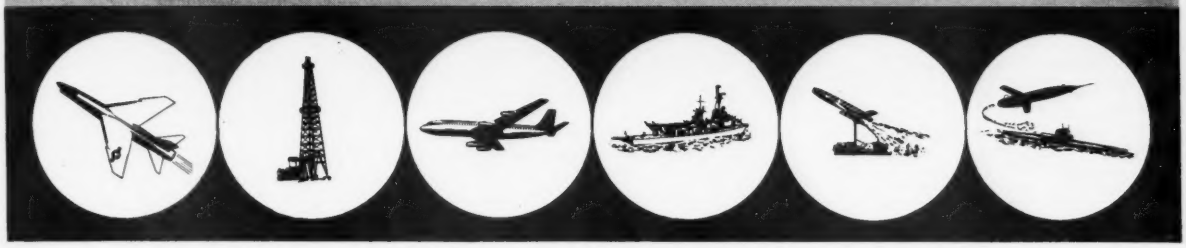

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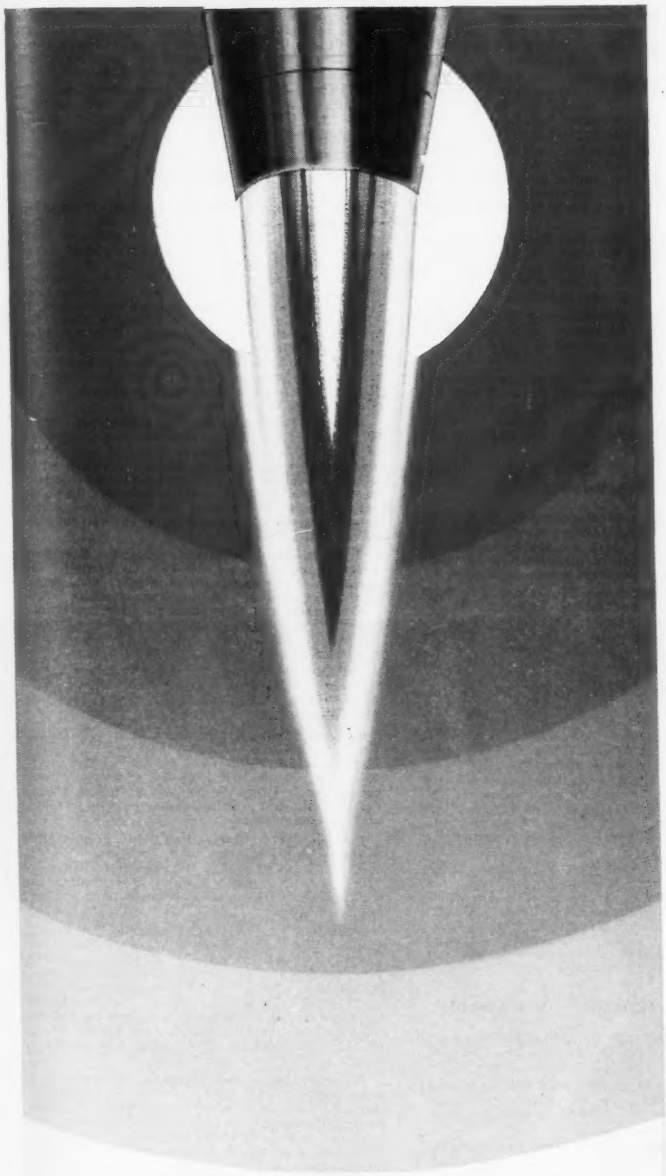

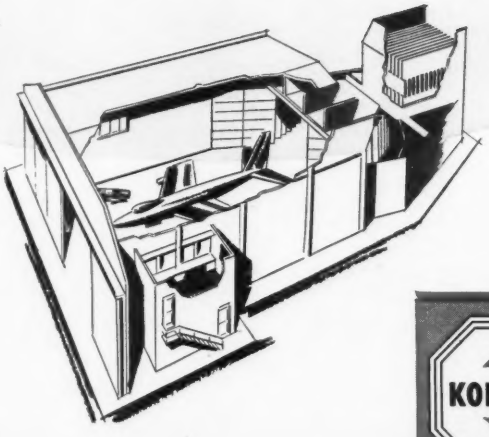

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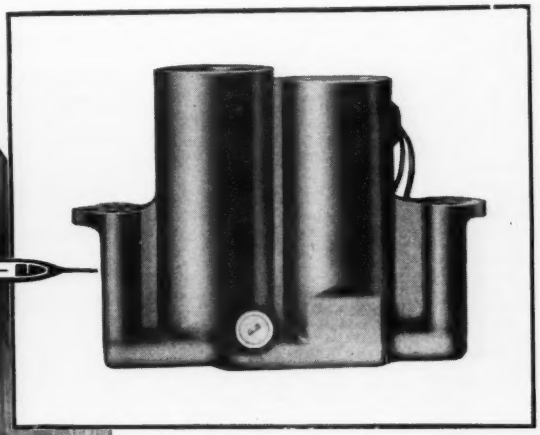

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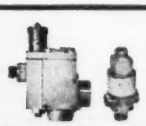

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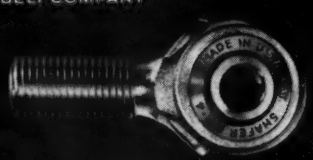

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Supersonic Civil Air Transports with Consideration of Potential VTOL Capabilities. James A. O'Malley, Jr. *IAS 26th Annual Meeting, New York, Jan. 27–30, 1958, Preprint 826.* 15 pp. 26 refs. Members, $0.50; nonmembers, $0.85. Discussion of supersonic speed capability, the VTOL capability presently available to industry, and the supersonic transport status.

Der Vertikalstart als Vortriebsproblem. K. W. Mack. *Luftfahrttechnik*, Jan. 15, 1958, pp. 1–16. 44 refs. In German. Survey of propulsion systems for VTOL aircraft, including evaluation of their respective characteristics and discussion of possible improved and new propulsion systems.

Research in the Field of Wingless VTOL Aircraft. A. M. Lippisch. *IAS 26th Annual Meeting, New York, Jan. 27–30, 1958, Preprint 808.* 11 pp. Members, $0.35; nonmembers, $0.75. Discussion of the evolution of the Aerodyne, including its aerodynamic characteristics and performance.

Rotodyne Report; Development Aspects and Commercial Applications of Fairey's VTOL Transport. *Flight*, Dec. 20, 1957, pp. 953–958, cutaway drawing.

Special Issue: Helicopter Progress and V.T.O.L. Survey. *The Aeroplane*, Dec. 13, 1957, pp. 872–900. *Partial Contents:* VTOL—The Ways and Means, David W. H. Godfrey. The Flat-Riser Solution. Elands for VTOL. Westland Activities. Building the Rotodyne Prototype. Sycamores in Cyprus, Peter Fahy. Development for a VTOL Jet Fighter. Current VTOL Aircraft Data.

Water-Borne Aircraft

Structural and Impact Loads for the Flexible Airplane During Water Landings. Edward Widmayer, Jr., and Robert H. Schwab. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 689.*) *J. Aero. Sci.*, Mar., 1958, pp. 161–170.

Assessment of the Possibility of Using Suction to Inhibit Cavitation on Cylindrical Sections. G. E. Thomas. *Gt. Brit., ARC CP 362*, 1957, 18 pp. BIS, New York, $0.54. Investigation including two cases: (a) flow past elliptic cylinders with suction applied over the entire forward half, and (b) flow past circular cylinders with suction applied over limited areas.

Wind Tunnels & Research Facilities

Moyens d'Essais de l'Etablissement Aéronautique de Toulouse. Basséguy, Affre, and Bélanger. *Tech. et Sci. Aéronautiques*, Oct., 1957, pp. 151–167. In French. Description of test facilities of E.A.T., the Aeronautical Establishment at Toulouse.

Strioscope Transportable Permettant l'Examen, à la Verrerie, des Glaces Destinées à la Visualisation Strioscopique en Souffleries. R. Chevalérias. *La Recherche Aéronautique*, Nov.-Dec., 1957, pp. 56–58. In French. Design and description of a portable device for streak detection in glass panels used for flow visualization in wind tunnels.

Development of the R.A.E. 6 inch Diameter Shock Tube. II—Design, Development and Early Use of a Simple Gas Stop Valve. S. G. Cox. *Gt. Brit., RAE TN Aero.2528*, Aug., 1957. 5 pp.

Appareil pour l'Utilisation en Soufflerie des Capteurs à Variation "d'Induction Mutuelle." Jacques Fiquet. *La Recherche Aéronautique*, Nov.-Dec., 1957, pp. 3–11. In French. Description of a device designed for using mutual-inductance pick-ups in wind-tunnel experiments. Includes discussion of various applications.

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IAS News *(Continued from page 68)*

Lockheed Aircraft Corporation's Georgia Division, where a test facility is being built.

He said aircraft components will be instrumented and exposed to radiation. Later they will be checked for exposure, and the amount of reactor shielding required to protect components will be determined.

H. A. Reichmann, Jr., *Secretary*

Tulsa Section

Computers Deciphered

Virgil Berry and R. E. Ruthrauff discussed "The Engineer's Use of High-Speed Electronic Computers" at the January 14 meeting. Dr. Berry is Supervisor, Research Group, Pan American Petroleum Corp. Mr. Ruthrauff is Supervisor, Computing Engineering, Tulsa Division, Douglas Aircraft.

Dr. Berry reviewed the history of computer development and outlined the capability of high-speed equipment. He said "one shot" problems are not suited for computers because of the time required to program the machine.

Mr. Ruthrauff described the IBM 701 high-speed equipment currently used by Douglas. He said this machine is particularly valuable in preliminary design because analyses can easily be redone as inputs are revised by design changes.

After the discussion, a sample problem using 3,500 instructions which required 2 man-months to program was fed to a 701 machine and solved in 4 min.

Bruce D. Olson, *Recording Secretary*

Wichita Section

Boeing Plant Visited

Some 135 members visited Boeing Aircraft Company's Wichita plant and engineering laboratory on January 8. Boeing host was Milford Vanick, Chief, Technical Staff, Engineering.

Members visited the manufacturing section where they saw newly installed, numerically controlled, automatic milling and riveting machines.

They saw the structural test, metallurgical, electronic, and power-plant laboratories and the engineering digital computing unit.

Lyman L. Peterson
Secretary Pro Tem

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AERONAUTICS, GENERAL

Jahrbuch 1956 der Wissenschaftlichen Gesellschaft für Luftfahrt e.V. (WGL). Herausgegeben von Hermann Blenk. Schriftleitung: Werner Schulz. Braunschweig, Friedr. Vieweg & Sohn, 1957. 267 pp., illus., diagrs., figs. DM 38.–.

Contents: Das Höhenzünden der Strahlturbinen (Ignition of Jet Turbines at Altitude), F. Ferrié. Anwendungsbeispiele zur technischen Reaktionsthermodynamik (Examples of Applications for Technical Reaction Thermodynamics), Otto Lutz. Absaugung in der Aerodynamik (Suction in Aerodynamics), Hermann Schlichting. Einige physikalische Betrachtungen über das Ausblasen an Tragflügeln (Some Physical Considerations on Blowing Applied to a Wing), Ph. Poisson-Quinton. Das meridianbeschleunigte Verdichterrad als Vorstufe eines vielstufigen Axialverdichters (The Compressor Rotor with Meridian Acceleration as the First Stage of a Multistage Axial Compressor), Hans Winter. Zur Stabilität des Hubschraubers (Stability of the Helicopter), H. Parkus. Der Flug mit hohen Geschwindigkeiten (High-Speed Flight), Günther Bock. Aufgaben und Methoden der Luftbildmessung (Problems and Methods of Aerial Photogrammetry), Rudolf Förstner. Structural Analysis by the Matrix Force Method with Applications to Aircraft Wings, J. H. Argyris and S. Kelsey. Das Herauskommen eines Flugzeugs aus einem Sturzflug mit hoher Geschwindigkeit (The Recovery of an Aircraft from a High-Speed Dive), A. D. Young and S. Neumark. Ein Verfahren zur Berechnung der Auftriebsverteilung an Tragflügeln bei Schallanströmung (A Method for the Calculation of the Lift Distribution on Wings in Transonic Flow), Erich Truckenbrodt. Ergänzungen zur Tragflächentheorie bei inkompressibler Strömung von E. Truckenbrodt (Additions to E. Truckenbrodt's Theory of the Lifting Surface in Incompressible Flow), Werner Niemz. Theoretische und experimentelle Untersuchungen an schiebenden Flügeln, insbesondere Pfeil- und Deltaflügeln (Theoretical and Experimental Investigations of Yawing Wings, Particularly Swept and Delta Wings), Karl-Heinz Gronau. Ein Invarianzkriterium für die Unter- und Überschallströmung an äquivalenten Körpern, insbesondere an Flügel-Rumpf-Kombinationen (An Invariance Criterion for Subsonic and Supersonic Flow Around Equivalent Bodies, Particularly Around Wing-Fuselage Combinations), Friedrich Keune and Werner Schmidt. Strahllärm, ein wissenschaftliches und technisches Problem der Luftfahrtforschung (Jet Noise, A Scientific and Technical Problem of Aeronautical Research), E. Koppe and E.-A. Müller. Über die Eignung von Gasturbinentriebwerken kleiner Leistung für den Antrieb von Flugzeugen (The Suitability of Low-Powered Gas Turbine Power Plants for Aircraft Propulsion), Wilhelm Pieper. Über die Entwicklung von kerbfeien Flugzeugteilen (The Development of Aircraft Parts Free from Notch Effects), Walter Bergmann. Zur Entwicklung von kerbfreien Flugzeugteilen; Überblick aus Arbeiten des Instituts für Werkstoffkunde der Technischen Hochschule Hannover (Toward the Development of Aircraft Parts Free from Notch Effects; Summary of the Work of the Institut für Werkstoffkunde, Technische Hochschule, Hannover), A. Matting. Vorschlag einer neuen Tragflügelbauweise (A Proposed New Method of Wing Construction), Otto Oeckel. Die Rechtsgestalt der Luftfahrzeughypotheken und das Luftfahrzeugbuch (The Legal Aspect of Aircraft Mortgages and the Aircraft Record), Georg Scholz. General, Administrative, and Activity Reports. Membership Roster.

AIRPLANES

Jet Operations Requirements Panel, Third Meeting, Montreal, June 17-28, 1957. Vol. 1, Report (Doc 7828, JOR/3-1); Vol. 2, Working Papers (Doc 7828, JOR/3-2). Montreal, Canada, International Civil Aviation Organization, 1957. Vol. 1, 235 pp., diagrs., tables, $2.50. Vol. 2, 137 pp., diagrs., tables, $1.50.

Contents: Volume 1: Address by the President of the Council. Address by the President of the Air Navigation Commission. Proposed Layout of Alger Maison-Blanche Airport, J. Guillot. The Ground Handling Problem, International Federation of Air Line Pilots' Associations. Examples of Aircraft Parking Systems, R. Broadbent. Runway Length Requirements. Graphs of Performance Data and Operational Factors.

Volume 2: Aerodrome Requirements for Jet Aircraft, IFALPA. RAC and ATS Requirements for Jet Aircraft, IFALPA. Meteorological Requirements for Jet Aircraft, IFALPA. Communications Requirements for Jet Aircraft, IFALPA. Difficulties Encountered in Telecommunications, R. H. Bulin. The Effect of Turbulent Wake from Large Jet Aircraft on Air Traffic Control Separation Criteria, J. Riley and R. Broadbent. The Role of Radar Control, H. Wood. The Role of Precise Navigation in an Air Traffic Control System, R. A. Pearson. Parking and Apron Handling of Turbo-Jet and Turbo-Prop Aircraft, R. Broadbent. Co-Ordination of Meteorological Information, T. N. S. Harrower. Main Characteristics of Turbine-Engined Aircraft. Jettisoning of Fuel from Jet Aircraft, A. L. Porri and R. Broadbent. Maximum ILS Glide Path Angles for Jet Aircraft, R. Broadbent. Location, Shape and Size of Holding Areas and Patterns, D. Blake. Trials on the Location of Holding Areas for Jets, D. Blake. Ingress of Debris into Turbo-Jet Engines, D. Ballantyne. A Study of the Advantage of Panoramic Radar for Future Traffic with Particular Reference to Jet Aircraft, R. H. Bulin. Choice of Telecommunications Methods, R. H. Bulin. Progress Report of Australian Research on Visual Problems of Approach to Landing; June 1957, R. W. Cumming and J. C. Lane.

Operating the Jet; A Symposium on the Turbine Aircraft. A Presentation to the Aviation Subcommittee of the Senate Interstate and Foreign Commerce Committee. Washington, Air Transport Association of America, 1958. 99 pp., diagrs.

Contents: The Anatomy of the Jet, Russell K. Rourke. Personnel Training Requirements for the Jet Age, John H. Halliburton. Maintaining and Supplying the Jet, Richard M. Adams. A Typical Transcontinental Flight, Marcy B. Fannon. Airport and Noise Considerations, W. E. Rhoades. Terminal Facilities for Turbine Aircraft, Marvin Whitlock. Airline Economics and the Jet Age, Stanley G. Gewirtz.

CIVIL AVIATION

CAA Statistical Handbook of Civil Aviation. 1957 Ed. U.S. Department of Commerce, Civil Aeronautics Administration. Washington, Superintendent of Documents, 1957. 135 pp., tables. $0.60.

Recognized as the standard summary of official statistical data on the status of civil aviation in the United States, this edition of the CAA *Handbook* includes all available statistics on major civil aviation activities through December, 1956. The *Handbook* serves as a convenient statistical reference volume for organizations and individuals active in all segments of the aeronautical industry.

DICTIONARIES

Russian-English Glossary of Solid State Physics. New York, Consultants Bureau, Inc., 1958. 90 pp. $10.

Primarily a compilation of Russian terms and expressions taken from numerous articles on various topics in solid-state physics, this glossary incorporates terms in the fields of solid-state theory, crystallography, physics of metals, metallurgy, ferromagnetism, etc. The more than 4,000 items included are from the pages of the most recent issues of Soviet physics journals, especially the *Journal of Experimental and Theoretical Physics*, the *Physics Section of the Proceedings (Doklady) of the USSR Academy of Sciences*, and the *Journal of Technical Physics*. A certain number of the most important terms of general quantum theory also are given, while the terminology of electronics is represented principally by expressions which are employed in Soviet papers on solid-state physics.

For Information on IAS Library Services, see page 70

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

DYNAMICS

Advanced Dynamics. John E. Younger. New York, Ronald Press Company, 1958. 285 pp., diagrs., tables. $8.50.

Prepared for students who have completed the usual junior-level courses in statics, dynamics, strength of materials, integral calculus, and differential equations, this text begins each analysis with the most elementary concepts of engineering dynamics, as a review, and then advances to problems of stronger technical interest. The advanced character of the summary problems, and the fact that analyses and solutions are given in detail, qualify the work to serve as a reference for practicing engineers.

The author is Professor of Mechanical Engineering, Department of Mechanical Engineering, University of Maryland.

COMPUTERS

The Preparation of Programs for an Electronic Digital Computer. Maurice V. Wilkes, David J. Wheeler, and Stanley Gill. 2nd Ed. Reading, Mass., Addison-Wesley Publishing Company, Inc., 1957. 238 pp., diagrs., tables. $7.50.

Thoroughly revised and expanded to include machines other than the Electronic Delay Storage Automatic Computer, this edition offers a general introduction to programing for any computer of the stored-program type. It is designed for those using electronic digital computers, for those putting new machines into operation, and for those wishing to assess the possible application of such computers to their own problems.

Dr. Wilkes and Dr. Wheeler are with the University Mathematical Laboratory, Cambridge University, while Dr. Gill is head of the Computing Research Group, Ferranti Ltd, London.

FILMS

The Giannini Film List; A Source Catalog of 16 mm. Unclassified, Released Aeronautical Films. Rev. Ed. Published by the IAS under the Auspices of the Giannini Film Library Fund. New York, IAS, 1958. 38 pp.

An alphabetical listing, by title, of films available for educational, nontheatrical showings on a loan basis, subject to the owner's discretion. Included are a source index giving the addresses to which loan requests should be made and tear-out post cards for making such requests.

HYDRAULIC EQUIPMENT

Aircraft Hydraulics: Vol. 2, Component Design. Edited by H. G. Conway. Published under the Authority of The Royal Aeronautical Society. London, Chapman & Hall, 1957; New York, The Macmillan Company. 198 pp., illus., diagrs., tables. $9.00.

Illustrated chapters deal with seal or gland design, pumps and motors, selectors, valves, pipe work and piping problems, miscellaneous components, and hydraulic servocontrols. The editor is Director and Chief Engineer, Short Brothers and Harland Ltd., Belfast.

INSTRUMENTS

Instrumentation in Testing Aircraft. C. N. Jaques. (Royal Aeronautical Society, Aeronautical Monographs, Vol. 5.) London, Chapman & Hall, Ltd., 1957. 291 pp., illus., diagrs. 45*s*. $6.30.

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The author was formerly Head, Instrumentation Department, Royal Aircraft Establishment.

MATERIALS

13th Annual Technical and Management Conference, Reinforced Plastics Division, The Society of the Plastics Industry, Inc., February 4-6, 1958, Chicago, Illinois. New York, The Society, 1958. 649 pp., illus., diagrs., tables. $7.00.

Partial Contents: Survey—Resin Developments, Dr. Johan Bjorksten. Evaluation of Organic Peroxides on the Basis of Half-Life Data, Donald F. Doehnert and Orville L. Mageli. Functional Inorganic Pigments for use as Reinforced Plastic Fillers, S. R. Mountsier, Jr., and A. J. Gitter. Properties of Reinforced Plastics Made From Acrylic Sirups, Mandell S. Ziegler, William H. Calkins, and Walter M. Edwards. Optimum Aromatic-Amine Hardened Epoxy-Glass Laminates, Harry Raech, Jr., and Frederick F. Harris. Dielectric Measurements for Process and Product Evaluation, John J. Knudsen. Improvement of Reinforced Plastics by Fibers From New Glasses, James W. Case, Albert Lasday, J. Frees Brossy, and Armand Houze. Mechanical Properties of Glass Reinforced Castings Resins, C. L. Segal. Glass Fabric-Base Laminate Physical Properties as a Function of Finishing Variables, Richard C. Horton and Henry S. Falls. Tensile Strength of Glass Fibers, J. A. Kies and R. E. McVicker. An Investigation of the Optical Properties of Fiberglass Reinforced Translucent Panels, John B. Crenshaw and Daniel Smith. Controlled Process Fabrics From Controlled Weight-Length Variation Yarns, William J. Eakins. Bond of Resin to Glass, A. C. Anderson and J. H. Healy. Proposed NOL Ring Test Method for Parallel Glass Roving Reinforced Plastics: Evaluation of Chemical Finishes, Porter W. Erickson, Irving Silver, and H. A. Perry, Jr. Long-Term Rupture Strength in Glass Reinforced Plastics, S. Goldfein. Unidirectional Glass Reinforced Plastic Ring Structures, N. Chessin. Creep Characteristics of Laminated Epoxy Plastics, John Delmonte. Laminates Reinforced with Asbestos, Norman E. Wahl and Harold M. Preston. Effects of High Intensity Thermal Radiation on Plastic Laminates, H. S. Schwartz and B. J. Lisle. Effects of Elevated Temperature and Erosion on Reinforced Plastic Laminates, Norman B. Miller and Eric L. Strauss. Radome Materials for Operating Temperatures Above 500°F., Francis Bozzacco and Paul Swanson. Behavior of Reinforced Plastics at Very High Temperatures, L. H. Shenker and I. J. Gruntfest. Subsonic and Supersonic Rain Erosion Problems, G. P. Peterson. A Comparison of Phenolic and Polyester Premix Materials, J. J. Colao and M. M. Gurvitch. Report of the Premix Standards Committee, Lawrence Wittman. Physical Properties of Transfer and Compression Molded Premix Materials, R. H. Calderwood and H. R. Sheppard. Applications and Suggested Uses of Polyester Premixes, C. W. Proudfit. A New High Strength Molding Material, S. G. Salzinger and Henry M. Toellner. The Pressurform Preform Process, S. H. A. Young. Fundamental Study of Adhesion, J. J. Bikerman. Resin-Glass Bond Characteristics, F. J. McGarry. Laminate Behavior as Determined from Interior Strain Measurements, Richard E. Chambers. The Influence of Several Resin and Process Variables on Polyester Laminate Properties, William G. Carson and Arthur L. Smith. Design and Operation of a Rosette Extensometer, Professors A. G. H. Dietz and F. J. McGarry. Vacuum-Pressure Injection Molding of a Reinforced Plastic Helicopter Contravane, Kurt A. Schneider. Simultaneous Deposition of Fiberglass and Resin as a Reinforced Plastics Manufacturing Technique, David F. Anderson. Development of a Reinforced Plastic Jato Motor, John J. Scavuzzo. Contour Weaving of Reinforcement, A. R. Campman and Edward Koppelman. Cure Shrinkage of Epoxy Resin Systems, H. L. Parry and H. A. MacKay. Filament-Wound Metal Composite Vessels, Robert L. Noland. Development of Improved Filament-Wound Pressure Vessels, George Epstein and Harry A. King. History and Potential of Filament-Winding, Richard E. Young. Filament-Winding Developments for Rocket Applications, Richard Gorcey.

Polyamide Resins. Donald E. Floyd. New York, Reinhold Publishing Corporation, 1958. 230 pp., illus., diagrs., tables. $4.50.

The purpose of this book is to discuss the various important applications of the polymers belonging to the polyamide resin family. With this objective in view, the book not only classifies the applications but also reviews the considerations and properties that make polyamide resins useful in these applications. In addition, an attempt is

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made to relate polyamide resin properties to resin composition and structure.

The author is head of the Chemical Applications Section, General Mills' Chemical Research Department.

Polyurethanes. Bernard A. Dombrow. New York, Reinhold Publishing Corporation, 1957. 176 pp., illus., diagrs., tables. $4.50.

This coverage of the uses and possibilities of the polyurethanes includes their many applications as foams, and as coatings, rubber (castings as well as tires), and adhesives.

The author is Director of Laboratories, Plastics Division, Nopco Chemical Company.

1957 Supplement to Book of ASTM Standards, Including Tentatives. Part 2, Non-Ferrous Metals. Philadelphia, ASTM, 1957. 378 pp., diagrs., tables. $4.00.

1957 Supplement to Book of ASTM Standards, Including Tentatives. Part 6, Plastics, Electrical Insulation, Rubber, Electronics Materials, Carbon Black. Philadelphia, ASTM, 1957. 424 pp., illus., diagrs., tables. $4.00.

MATHEMATICS

Mathematics and Wave Mechanics. R. H. Atkin. New York, John Wiley & Sons, 1957. 348 pp., diagrs. $6.00.

This introduction to wave mechanics consists of a number of introductory chapters on both pure and applied mathematics which are then followed by discussions of some of the more important applications of quantum theory. The level of mathematics required of the reader is that normally reached prior to entry to a university.

The author is Lecturer in Mathematics, Northern Polytechnic, London.

PATENTS

Ideas, Inventions, and Patents; How to Develop and Protect Them. Robert A. Buckles. New York, John Wiley & Sons, Inc., 1957. 270 pp., illus., diagrs. $5.95.

Intended primarily for engineers and scientists engaged in research and development activities—and for those businessmen engaged in planning and managing industrial enterprises in which inventions, patents, and trademarks play a role—this book presents in broad general outlines the fundamental principles and philosophy of the laws respecting "intellectual property" for the purpose of pointing the way to more effective protection and exploitation of ideas and inventions. After discussing the principles that underlie patents in all fields of technology (mechanical, electrical, chemical, and nuclear) and giving lucid examples of specific applications in each area, the author takes the reader step by step through the complete history of a simple invention.

The author is a practicing patent attorney and a member of the New York Bar.

PHYSICS

An Introduction to Scale Coordinate Physics; An Introduction to the Formalization of the Macro Operational Point of View. William Bender. Minneapolis, Minn., Burgess Publishing Company, 1958. 340 pp., diagrs., tables. $7.50.

One of the major objectives of this essay is to lay the foundations of a point of view in physics upon which the empirical data of quantum mechanics may be comprehended in terms of the *gross operations on, and gross configurations of, physical apparatus.* A new mathematical tool, called the *scale coordinate*, is employed for purposes of computing the ordinal and cardinal relationships among properly dimensionalized physical entities.

The author is Professor of Physics and Head, Department of Physics, University of South Dakota.

SPACE TRAVEL

Satellites and Space Flight. Eric Burgess. New York, The Macmillan Company, 1957. 159 pp., illus., diagrs., tables. $3.95.

Presentation of a scientific account of the development of earth satellites, including details on construction, instrumentation, launching procedure, transmission of data, and flight orbit. Proceeding from the satellite to the organization of a spaceflight program, attention is given to the physiological and psychological problems concerned with manned rockets and the establishment of a manned station in space. Expeditions to the moon and the planets are also examined.

The author is a Fellow and a past Chairman of the British Interplanetary Society.

Space Flight and Satellite Vehicles. R. B. Beard and A. C. Rotherham. New York, Pitman Publishing Corporation, 1958. 150 pp., illus., diagrs. $3.95.

This book surveys the present stage of development and assesses future trends in interplanetary flight. It is written with the object of giving the reader who has a real interest in the subject and who has some basic scientific knowledge an appreciation of the principles involved and of the problems to be overcome. The authors, both of whom are members of the British In-

(Continued on page 121)

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to Aeronautical specialists. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Assistant Professor and Instructor in Aeronautical Engineering—Positions are open for teaching and research in several subjects. An advanced degree is required for the rank of Assistant Professor. Send résumé of education, experience, and field of interest to Chairman, Aeronautical Engineering Department, University of Kansas, Lawrence, Kan.

Engineers—Needed for expanding program of helicopter development. Airframe and controls designers, helicopter experience desirable; mechanical designers, helicopter transmission or engine transmission experience desirable: instrumentation and electronics engineers, particularly with experience in automatic stabilization and control of droned aircraft. Also test pilots with helicopter test experience. Write to: Personnel Director, Gyrodyne Company of America, Inc., St. James, Long Island, N.Y.

Engineers—Fairchild Engine Division of the Fairchild Engine and Airplane Corporation, Deer Park, Long Island, N.Y. Diversified engineering positions are available involving engine research, design, design and performance analysis, test-engineering, compressor and turbine design, controls systems, and other engineering operations associated with the general field of design and development of gas turbine power plants. These opportunities result from expanded programs in a new plant and Gas Turbine Laboratory. Send résumé to: Felix Gardner, Fairchild Engine Division, Deer Park, Long Island, N.Y.

Senior Structures Engineers—With advanced degrees and experience are required for structural analysis, structural design, design of high-temperature structures, flutter, aeroelastic effects, and dynamics. Supervisory positions available. For further information write Staff Placement, Aeronutronic Systems, Inc., 1234 Air Way, Glendale, Calif.

849. Assistant or Associate Professor—Needed September 1, 1958, to teach aeronautical courses—aerodynamics, airplane structures, design, laboratory. Must have a Master's degree in aeronautical engineering and preferably teaching and industrial experience. State education, experience, references, and salary expected.

847. Designers—We presently need approximately ten high-caliber designers with extensive electronic experience (7–10 years). They should be adept at packaging, chassis, and printed circuit work. They should have the ability to take a schematic and from it know how components should be placed on the chassis or printed circuit board.

Available

855. Engineer—B. S. in Ae. E. and M. E. One years' experience as analytical engineer in performance analysis of jet engines and gas turbines and 1 year's experience in mechanical design of machines. Résumé furnished on request.

854. Engineer—Executive—Age 40, B.S.M.E., Purdue and Stanford Universities. Twelve year's experience in aeronautical research, development, and test; 6 years' experience in engineering sales and general industrial engineering; licensed. Four years of foreign work, Europe and Latin America, as engineer in Diplomatic Service; speaks French, Spanish, Italian. Relatively recently with research and engineering, Office of Secretary Defense, Pentagon. Last position Assistant to Vice-President, Foreign Operations, top engineering-construction organization. Former officer Marine Corps Aviation; licensed pilot. Top level contact work past 10 years. Available for foreign or domestic assignment any location and any amount of travel; married, no children. Interested particularly in engineering sales and/or management in position paying upwards of $18,000. Will send complete résumé on request.

853. Aeronautical Engineer—Age 33; 16 years' aviation experience. B. S. Aero. Presently production engineer on gas turbine aircraft engines. Desires shift to missile propulsion, static or flight testing. Résumé on request.

852. Aerodynamics Engineer—Aircraft, missile and propulsion fields. Available for part-time consulting in New York area. Twelve years' experience in subsonic and supersonic aircraft design, ram-jet and turbo-jet performance and research. Interested in active engineering, technical editing or technical adviser in research and/or development investment for domestic and European companies, in the areas outlined above. Résumé of educational, industrial and research experience, and accomplishments available on request.

851. Engineer—B. S. in M. E. Eleven years' experience as stress, design, and project engineer on rotary wing aircraft; 12 years' experience as stress and test engineer on fixed-wing aircraft. Desires position on East Coast where experience would be useful on varied assignments in aircraft or missile field with greater responsibility. Résumé furnished on request.

850. Engineering Management—B.M.E., Age 39. Sixteen years' engineering experience in the aircraft and allied industries. Last 6 years in supervisory capacity planning, organizing, and directing guided-missile and piloted aircraft electromechanical systems development programs; 1 year in electromechanical design; 7 years in flight research; 2 years in stress analysis. Current assignment as assistant section head of research, development, and technical proposals section for electromechanical subsystem manufacturer. Current salary over $13,000 per annum. Desires position with greater management responsibility. Location either coast. Résumé furnished on request.

846. Representative—For the business concern which requires a competent representative for the United States and/or overseas; emphasis on sales and sales development for a tangible or intangible. Candidate contemplates a change and offers these assets: now in tenth year successfully selling a confidential business service to top management. A graduate mechanical and aeronautical engineer with 20 years' engineering background in sales, preliminary design, flight test, teaching, etc., and patents (aviation gas turbines). Member, A.A.F. special mission, World War II—aeronautical technical intelligence. Also, can read, write, and speak German, French, Russian, fluently. Extensive travel abroad and in United States has made him familiar with the idiosyncrasies and ideologies of your prospective customers in Europe, Near East, and Africa. Effective speaker-lecturer. Mature (50), married, excellent health. Prefers salary plus commission. Please send an outline of your offer and suggested date for personal interview.

845. Teacher-Administrator—B.S. in A.E. and M.S. in M.E., 10 years' experience in teaching, 10 years in aerodynamic research, experienced in industrial personnel and management training activities, presently engaged in a writing project, desires a teaching or teaching-and-administrative position in a college or university beginning with the fall term 1958. Location in the south or southwest desired. Opportunities to challenge and advise students are of greater importance than academic rank or salary.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Books (Continued from page 120)

terplanetary Society, consider public acceptance of the feasibility of astronautics essential to its future development.

THERMODYNAMICS

Thermodynamics of Heat Power. Virgil Moring Faires. New York, The Macmillan Company, 1958. 432 pp., illus., diagrs., tables. $8.00.

Adopting the modern concept of thermodynamics as a logical and unified discipline, this book places its major emphasis on the development and application of theory, especially as applied to steady flow systems. The work also contains descriptive material aimed at students other than mechanical engineering majors, and each chapter is accompanied by a set of problems to which answers are supplied.

The author is Professor of Mechanical Engineering, North Carolina State College.

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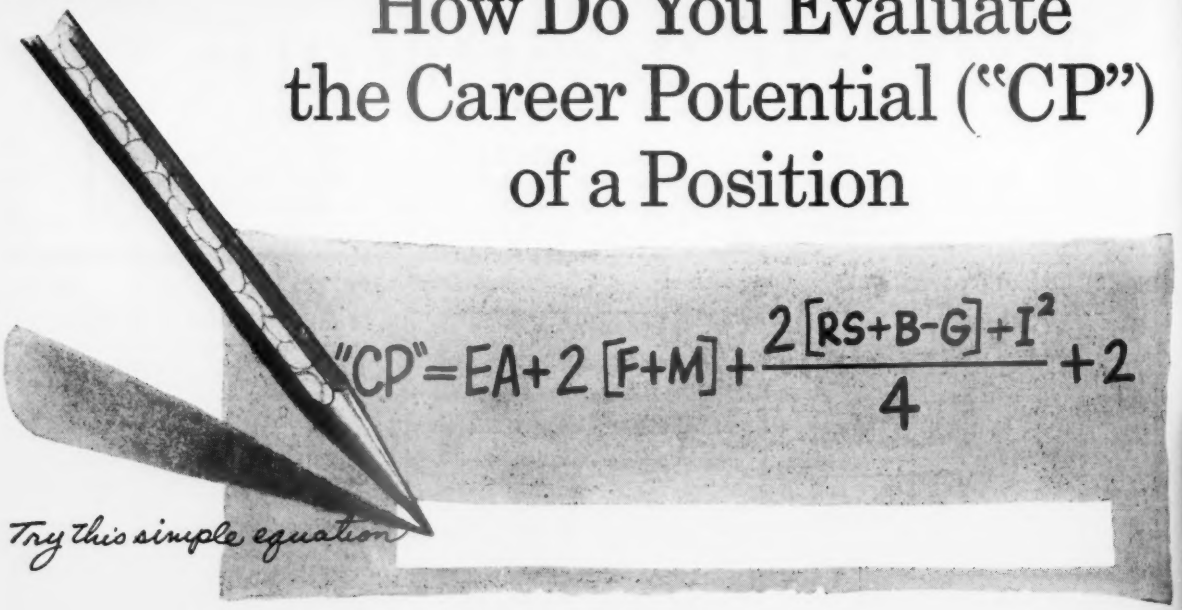
ENGINEERS

How Do You Evaluate the Career Potential ("CP") of a Position



My Present "CP"=_____

"CP" VALUES; to test your "CP," circle the value you'd give each symbol below, substitute, AND SOLVE. *(Top value obtainable, 99.5)*

	"CP" VALUES	LOW			HIGH
E	Encouragement to Exercise Initiative & Creative Imagination	2	3	4	5
A	Assignment (Nature of)—from Routine to Very Challenging	5	6	7	8
F	Field—Conventional Product to Area where Technical Breakthroughs Expected	2	3	4	5
M	Modern Facilities—from Limited to Extensive Equipment for Testing and Research	2	3	4	5
R	Recognition of Individual Contributions—Chief Reason for Advancement	2	3	4	5
S	Salary—from Unsatisfactory to Excellent for Level of Work	5	6	7	8
B	Benefits—from Limited to Best in Industry, including Encouragement to Join Professional Societies; Liberal Support for Graduate Study	2	3	4	5
G	Increases—Primarily by Seniority Rather than Merit.	2	3	4	5
I	Your Individual Skill, Creativeness and Ability to Take Responsibility	5	6	7	8

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Mr. George Hickman, Engineering Employment Manager

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